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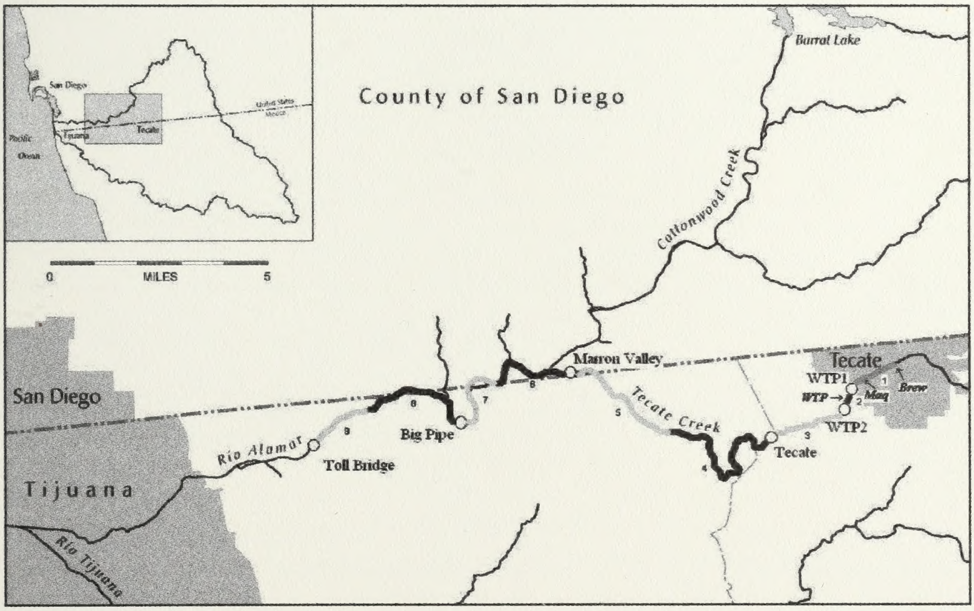
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SOUTHERN CALIFORNIA ACADEMY OF SCIENCES

CALL FOR PAPERS

2005 ANNUAL MEETING

May 20–21, 2005

LOYOLA MARYMOUNT UNIVERSITY

LOS ANGELES

The Southern California Academy of Sciences will hold its 2005 annual meeting on the campus of the Loyola Marymount University, Los Angeles. Presently planned symposium topics are listed below. Additional proposed symposium topics are invited. Please contact John Dorsey (*jdorsey@lmu.edu*) to propose additional symposia.

Details of the meeting, announcements and general instructions for pre-registration, abstract preparation and submittal are given on the meeting web site at http://scas.jsd.claremont.edu/. Contributions may be in any area of science or mathematics. In recent years, papers have concentrated in the fields of marine and aquatic biology, terrestrial biology, ecology, systematics, population biology, biogeography and geology.

Planned Symposia Friday, May 19, 2005

Wetland Ecology: work on coastal marshes and their pollution.

Ecology of Nearshore Reefs: a continuing symposium on the ecology of rocky substrates.

Archeology of Southern California: devoted to studies of California prehistory.

Paleontology of Southern California: recent discoveries on the prehistory of our area.

Planned Symposia, Saturday, May 20, 2005

Fire Ecology: Studies of recent wildfires in southern California.

Avian Biology: Work on Southern California avifauna, especially endangered species.

SETAC: The Society of Environmental Toxicology and Chemistry will hold Three sessions on **New Frontiers in Environmental Chemistry,** as follows:

Tools for tracking the fate of wastewater derived contaminants in effluent dominated waters
Contaminant fate and source tracking using chiral and stable isotopic signatures
Chemical methods for measuring bioavailability

Contributed papers: Sessions of Contributed Papers will occur both days.

In addition, High School members of The Junior Academy will Present their papers on Saturday.

Plenary Speakers will be:

Friday: **Dr. Brian Fagan** "Fish on Friday: How Catholic Doctrine of Eating Fish on Friday Changed History"

Saturday: **Dr. James Powell**: "Death of the Dinosaurs: Bad Genes or Bad Luck?"

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Biological Assessment of Tecate Creek (U.S.–Mexico) with Special Regard to Self-Purification

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Jerome Pitt,[2] and Richard M. Gersberg[2]*

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Abstract.—Macroinvertebrate organisms were sampled at four sites on Tecate Creek (U.S.–Mexico) and quantitatively evaluated using the SIGNAL-w (Stream Invertebrate Grade Number—Average Level-weighted) index. A morphological assessment of the stream structure was also carried out. Bioindication by SIGNAL reflected a very low water quality in the upper three sampled stream reaches, but with a significant improvement by the last site on the Rio Alamar, but only to a grade of critical to high pollution over a flowing distance of 29 km. Levels of BOD and ammonium-N at the Rio Alamar (Toll Bridge) site remained quite high, 56 mg/L and 48 mg/L, respectively. Metal levels also generally decreased as the water flowed downstream to the the Rio Alamar. Despite the fact that Tecate Creek has a quite natural morphological structure, solid inorganic surfaces and aquatic macrophytes (as settlement area) are mostly absent in Tecate Creek. This lack of stable habitats prevents the development of an effective biofilm which would significantly enhance self-purification.

The Tijuana River Watershed (TRW) is a binational watershed on the U.S.–Mexico border, encompassing much of the cities of Tijuana and Tecate in Mexico and portions of the City and County of San Diego in the U.S. The basin contains three surface water reservoirs, various flood control works, and a National Estuarine Sanctuary in the U.S. which is home to several endangered species. For decades, raw and poorly treated sewage from the cities of Tijuana and Tecate, Mexico has flowed into the Tijuana River and across the international border into the United States. Pollution in Mexico has been caused by rapid population growth and urbanization, poor land-use practices, and inadequate sewage treatment and collection facilities in the watershed (Ganster 1996). A fast growing aspect of industry near the border has been the "maquiladoras." The term "maquiladora" refers to an industry established under a special customs allowance, mostly non-Mexican operations to establish manufacturing plants in Mexico that are allowd to import duty-free raw materials, equipment machinery, and replacement parts (Turner et al. 2003). The maquiladora industry, fueled primarily by foreign investment, has grown faster than the capability of the municipality to deliver services to them. Moreover, the lack of pollution prevention measures for industry and other businesses in Mexico, coupled with a deficiency in proper

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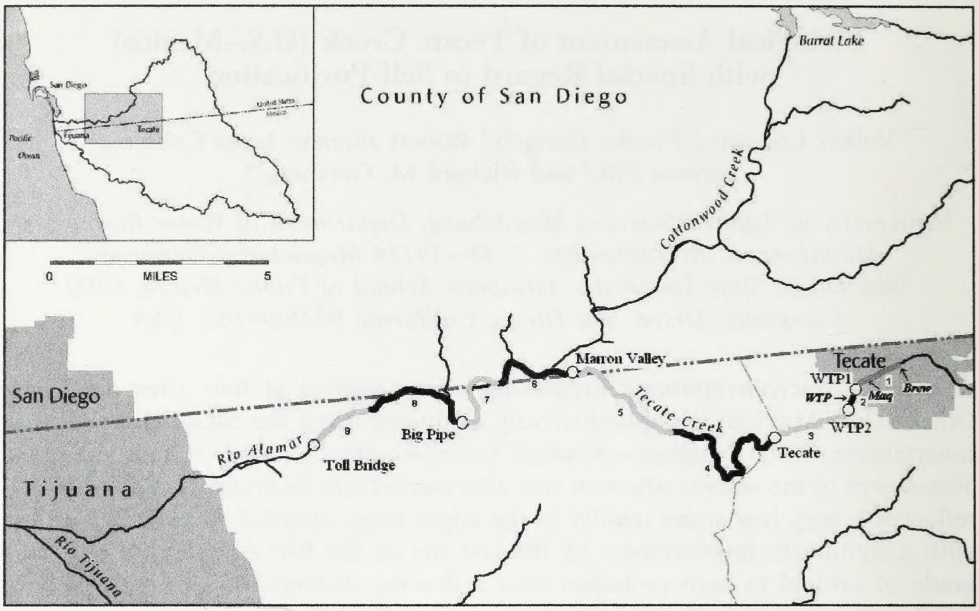
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Fig. 1. Map of sampling sites (denoted by open circles) on Tecate Creek and the Alamar River. Shaded (both light and dark) sections of stream segments represent reaches where ecomorphological assessment was made. The location of the discharge from the Tecate Municipal Wastewater Treatment is denoted as "WTP". The location of the discharge from the Tecate Beer Brewery and the Tecate maquiladora complex are denoted by "Brew" and "Maq" respectively. Map adapted from the Tijuana River Watershed GIS database. 2000.

enforcement of existing regulations, has generated pollution that contaminates the tributaries of the Tijuana River and ultimately the Pacific Ocean.

The city of Tecate, Mexico is located in the eastern section of the Tijuana River watershed (Figure 1). In 2000, the population of Tecate was nearly 80,000 persons, with this number expected to increase to around 150,000 by the year 2020 (INEGI 2000). In urban Tecate, major point sources of pollution to Tecate Creek include the discharge of poorly treated sewage from the Tecate Municipal Plant, the discharge of high BOD-containing waters from the Tecate Brewery, and effluent discharge from a maquiladora complex which includes a large metal-working industry and the effluent from a slaughterhouse. Due to these discharges, flow in Tecate Creek occurs throughout the year, even during the summer dry season when the stream would naturally have little or no flow. Downstream, Tecate Creek joins Cottonwood Creek in the U.S. to form the Rio Alamar (Figure 1), which eventually joins the Rio de las Palmas in Mexico to form the Tijuana River. Due to the major point sources of pollution mentioned above, as well as typical urban non-point sources, Tecate Creek may account for a significant part of the loading of a variety of pollutants to the downstream Tijuana River watershed and the Tijuana River Estuarine Research Reserve in the U.S. (Englert et al. 1999; Gersberg et al. 2000; Gersberg et al. 2002).

The purpose of this study was to measure the degree of contamination in Tecate Creek, and the extent to which these contaminants, including heavy metals, organic pollution (BOD and COD), nutrients (N and P), and fecal indicator bacteria, are reduced by self-purification downstream. An additional aim was to perform an integrated biological assessment of Tecate Creek to determine the effects of such pollution on the ecological development potential in this stream. Our overall ecomorphological investigations also allowed an examination of the potential of this stream for restoration efforts that could improve water quality in the Tijuana River watershed.

Materials and Methods

Chemical and Microbiological Assessment

In January and February 2002, water samples were taken four times from five sites on Tecate Creek and the upper Rio Alamar. The sites were: WTP 2 (downstream of the Tecate Municipal Wastewater Treatment Plant), Tecate, Marron Valley, Big Pipe, and Toll Bridge on the Rio Alamar (Figure 1). Sampling was done at each site over a period of one hour, where each sample represented a composite sample of 6 grab samples taken every 10 minutes. Samples were analyzed for dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), the heavy metals cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), and zinc (Zn), the plant nutrients (nitrogen and phosphorus), and total and fecal coliform bacteria. At an additional site (designated WTP 1, upstream of Tecate Municipal Wastewater Treatment Plant) samples were only analyzed for metals. To be sure that our samples approximate the same parcel of water as it moved downstream, the "flowing-wave"-method (Heidenwag et al. 2001) was used. This method involved measuring average flow velocities (Global FP201 Flow Probe) at each of the sites, calculating the average time of flow downstream to each site, and timing the sampling at successive sites to correspond with the flow of water.

Samples were analyzed according to the *Standard Methods for the Examination of Water and Wastewater* (APHA 1995). Chemical oxygen demand (COD) which reflects the level of organic carbon, was measured by the reactor digestion method. Biological oxygen demand (BOD) which reflects the level of assimilable organic carbon, was estimated by the 5-day BOD incubation test. The plant nutrients nitrogen and phosphorus were measured by colorimetric methods. Nitrate was analyzed by the cadmium reduction method. Ammonium was measured by the nesslerization method. Phosphorus was measured by the ascorbic acid method. Total coliforms and fecal coliforms were counted according to the most-probable-number method (MPN). For metals analysis, water samples were filtered using cellulose acetate membrane filters (0.45 μm-pore-diameter). Filtrates were acidified to pH 2 with concentrated nitric acid and used directly for Cd, Cr, Cu, Ni, and Pb dissolved metal analysis (APHA 1995). This analysis was performed using a Perkin-Elmer (SIMMA 6000) Graphite Furnace Atomic Absorption Spectrometer (AAS). Zn was analyzed by flame atomic absorption spectrometry using a Buck Scientific flame atomic absorption spectrophotometer (Model 210 VGP). For particulate metal analyses, filters were digested using concentrated nitric acid (APHA 1995). QA/QC included the use of reagent blanks, duplicate samples, recovery of standard concentration, and calibration of standards. Mean percent variation among the duplicates for all metals tested ranged from 2.3%–15.9%. Mean ($n = 3$) sample recoveries from a trace element calibration standard (2709

San Joaquin soil, National Institute of Standards and Technology) ranged from 94.4 to 101.0% for all of the metals tested. Self purification performance was calculated by dividing the pollutant concentration difference (mg/L) or bacterial density (MPN/I00 mL) difference at the first (upstream) and last sampling sites by the flowing distance (km) between them.

Hydrobiological Evaluation

Between October and December 1999, from July till September 2000, and from November 2001 to January 2002, macroinvertebrate organisms were sampled altogether three times in four 100 meter reaches (WTP 2, Tecate, Marron Valley (U.S.), Toll Bridge; see Figure 1) always over a period of one hour. Thereby, all biotope structures (bottom substrate, aquatic plants) were sampled by means of a handnet with a mesh size of 0.5 mm. The organisms were fixed in ethanol (70%) and estimated according to Merrit and Cummins (1996). Biotic Index according to Chessman (1995) was calculated. This calculation is based on the fact that numerous families of macroinvertebrates that are widespread in river systems nearly all over the earth have been awarded sensitivity grades according to their tolerance or intolerance of common types of pollutants as summarized by Chessman (1995). However, in some cases the grades are necessarily a compromise, either because of variation in the sensitivities of species within a family or because some families are sensitive to certain types of pollutants but relatively tolerant to others (Chessman 1995). The index SIGNAL-w (Stream Invertebrate Grade Number—Average Level, weighted by the occurrence) was calculated by multiplicating the grade of each family present by the value to represent its occurrence level (e.g. 1 for only 1 individual, 7 for mass development), summing the products, and dividing by the sum of the occurrence values.

Ecomorphological Assessment

Using the methods of ecomorphological mapping according to Lüderitz et al. (1996) and Heidenwag et al. (2001), the 29 km of the streamcourse of Tecate Creek (and the upper section of the Rio Alamar) were mapped and evaluated in 9 reaches shown in Figure 1.

The following main parameters were registered:

- stream course development
- lengthwise profile
- crosswise profile
- bottom structure
- bank structure
- structure of surroundings

These 6 main parameters are joined by 27 single parameters; an overview is given in Table 1.

The quality of ecomorphology is evaluated by 7 classes of structure grade:

Grade 1: not disturbed, natural morphology
Grade 2: slightly disturbed, unimportant changes which do not influence functionability of the waterbody
Grade 3: moderately disturbed, changes of morphology are obvious and disturb the ecology of the waterbody to a measureable degree

Table 1. Results of Ecomorphological Assessment at selected stream reaches[1] of Tecate Creek/Alamar River.

Main parameter	Individual parameters at different mapping sites	1	2	3	4	5	6	7	8	9	Average
1. Stream course development	Course bending	4	4	3	2	2	2	2	3	3	3
	Bending erosion	4	3	3	3	1	1	2	2	2	2
	Lengthwise banks	3	2	2	2	1	1	2	2	1	2
	Special course structures	2	2	1	1	1	1	1	1	1	1
	Average	3	3	2	2	1	1	2	2	2	2
2. Lengthwise profile	Crosswise constructions	3	1	1	1	1	1	1	1	1	1
	Backwater	2	1	1	1	1	1	1	1	1	1
	Piping	1	1	1	1	1	1	1	1	1	1
	Crosswise banks	2	3	2	1	2	2	2	2	2	2
	Current diversity	3	1	2	2	2	2	1	1	1	2
	Depth variation	2	2	2	2	1	1	2	2	2	2
	Average	2	2	2	1	1	1	1	1	1	1
3. Crosswise profile	Type of profile	2	2	3	1	1	1	1	1	1	1
	Depth of profile	1	2	3	1	1	1	2	1	1	2
	Bank erosion	3	2	3	1	1	1	2	1	1	2
	Width variety	3	3	3	2	1	1	2	2	2	2
	Culverts	7	1	7	1	1	1	1	1	4	3
	Average	3	2	4	1	1	1	2	1	2	2
4. Bottom structure	Bottom substrate	5	5	6	5	2	3	3	2	3	4
	River bottom protection structures	1	1	1	1	1	1	1	1	1	1
	Special natural bottom structures	3	1	3	3	2	1	1	1	1	2
	Substrate diversity	5	4	5	4	3	2	3	2	2	3
	Average	4	2	3	3	2	2	2	2	2	2
5. Bank structure	Bank trees	3	2	2	1	1	2	1	1	2	2
	Bank vegetation	3	2	3	2	1	2	2	1	2	2
	Bank paving	1	1	1	1	1	1	1	1	1	1
	Special natural bank structures	4	2	2	1	2	3	3	2	3	2
	Average	3	2	2	1	1	2	2	1	2	2
6. Surroundings	Area use	4	2	4	2	2	2	2	1	2	2
	Protection zones	4	2	3	2	2	2	2	1	2	2
	Adverse Structures	6	5	6	2	2	1	5	2	4	4
	Average	5	3	4	2	2	2	3	1	3	3
Final evaluation		3	2	3	2	1	2	2	1	2	2

[1] Stream reaches sampled and designated here 1–9 are shown on map (Figure 1).

Table 2. Land use characterization of Tecate Creek/Alamar River sub-basin drainage area downstream of urban Tecate, Mexico.[1]

Description	Hectares	Percent area
Commercial	36.70	0.31
Dispersed residential	95.11	0.80
Disturbed/under construction	358.48	3.01
Extractive industry	51.74	0.43
Improved pasture	55.90	0.47
Industrial	52.83	0.44
Institutional	13.46	0.11
Non-developed	10,197.70	85.58
Open grazeable land	536.20	4.50
Recreation	130.60	1.10
Residential	113.44	0.95
Row crops	91.33	0.77
Transportation	142.85	1.20
Tree crops	34.72	0.29
Water body	4.65	0.04
Total Area in Acres	11,915.79	100.00

[1] Tijuana River Watershed GIS database 2000.

Grade 4: clearly disturbed, waterbody shows a clear distance from natural status, is straightened and lined to a degree up to 50%
Grade 5: markedly disturbed, straightening and lining reach a percentage of 100
Grade 6: heavily disturbed, natural dynamics are avoided by bank pavement and lining
Grade 7: excessively disturbed, channelization is complete

Morphological assessment was done by comparing undisturbed stream reaches upstreams of Tecate (reference reaches) with the mapped sites.

Results

Tecate Creek has quite natural morphological structures, almost without typical problems like lining, straightening, and bank paving (Table 1). Expressed as a meander valley river and braided system, it shows a flat type of profile with a natural course with meanders and lengthwise banks, as well as a relatively high current diversity and depth variation. It generally has natural bank vegetation consisting of loose trees and shrubs. There are no dams or backwaters (and few culverts) on Tecate Creek. Downstream of Tecate, there are no adverse structures or any intensive landuses (Table 2). Indeed, downstream of urban Tecate, 90% of the land area that drains into Tecate Creek or the upper Alamar River, is either undeveloped or open grazable land, with industrial, commercial, and residential land uses (combined) only comprising less than 2% of the area (Table 2) (Tijuana River Watershed GIS database 2000). This data supports our visual observation that there are no major pollutant sources downstream of urban Tecate that would confound our analysis of self-purification efficiencies.

On the other hand, the substrate of Tecate Creek is very uniform (gravel partially filled with sewage sludges) and the river is oversaturated with these sediments (braided system). Solid surfaces are very rare, and biofilms that play an

Table 3. Settlement of representative sites on Tecate Creek/Alamar River with macroinvertebrates used for SIGNAL-w calculation.

Sample site	Family (genus species)	Sensitivity grade	Occurrence	SIGNAL-w
WTP2	*Psychodidae* (*Psychoda* sp.)	2	4	1.5 (excessively polluted)
	Culicidae	2	2	
	Chironomidae	1	2	
	Tubificidae (*Tubifex tubifex*)	1	4	
Tecate	*Psychodidae* (*Psychoda* sp.)	2	2	1.7 (excessively polluted)
	Chironomidae (*Chironomus* spp.)	1	1	
	Stratiomyidae	2	1	
	Ceratopogonidae	6	1	
	Tubificidae (*Tubifex tubifex*)	1	7	
Marron Valley	*Psychodidae* (*Psychoda* sp.)	2	2	2.1 (heavily polluted)
	Chironomidae (*Chironomus* spp.)	1	3	
	Ceratopogonidae	6	1	
	Tabanidae	5	1	
	Coenagrionidae (*Agria* sp.)	7	1	
	Tubificidae (*Tubifex tubifex*)	1	7	
Toll Bridge	*Psychodidae* (*Psychoda* sp.)	2	2	3.1 (critically polluted)
	Chironomidae (*Chironomus* spp.)	1	2	
	Tabanidae (*Chrysops* sp.)	5	1	
	Simulidae (*Simulium venustum*)	5	1	
	Coenagrionidae (*Ischnura* sp. *Argia* sp.)	7	2	
	Aeshnidae (*Anax* sp.)	6	1	
	Belostomatidae (*Belostoma* sp.)	5	1	
	Dytiscidae (*Rhantus* sp.)	5	1	
	Gammaridae	6	1	
	Tubificidae	1	7	

outstanding role in self-purification can develop only poorly due to this fact, and because of the friction between sediment particles which leads to a lack of stable habitats. Microscopic observation showed that very thin biofilms formed by filamentous bacteria and algae only existed on about 10% of the gravel surface.

Bioindication by SIGNAL-w reflects a very low water quality with index values of 1.5 to 2.1 in the upper three sampled stream reaches at WTP 2, Tecate, Marron Valley (Table 3). By the last site (Toll Bridge) on the Rio Alamar, there was significant improvement, but even here the index value of 3.1 represented a system still critically polluted (Table 3). Macroinvertebrate settlement at all sites is dominated by those Diptera larvae and Tubificidae which do not demand a high water quality; their high abundances indicate a polysaprobic status (i.e. a very high organic load).

Sampling for this study was all conducted under dry weather (baseflow) conditions when Tecate Creek was polluted to a very high degree with organic substances, plant nutrients, heavy metals, and fecal indicator bacteria (Table 4, Figures 2–7). With regard to self-purification, we found only a poor performance concerning organic substances and nutrients. Over a distance of 29 km (from site WTP 2 to the Toll Bridge on the Rio Alamar), BOD decreased only by 53% (2.14 mg/L km), COD by 84% (14.31 mg/L km), ammonium by only 4% (0.07 mg/L km), and total P by 51% (0.32 mg/L km). However, even this modest reduction

Table 4. Self-purification of Tecate Creek/Alamar River over a distance of 29 km as measured at 5 sampling sites.

Parameter	Units	WTP 2	Tecate	Marron Valley	Big Pipe	Toll Bridge
BOD	(mg/L) ± Std	118 ± 15	133 ± 12	47 ± 10	27 ± 8	56 ± 7
COD	(mg/L) ± Std	492 ± 68	379 ± 5	177 ± 29	122 ± 23	77 ± 28
DO-saturation	(%) ± Std	48 ± 11	23 ± 13	71 ± 6	65 ± 4	59 ± 7
NH4+-N	(mg/L) ± Std	50.3 ± 3.3	55.3 ± 6.2	58.0 ± 2.5	53.8 ± 4.8	48.3 ± 2.4
TP	(mg/L) ± Std	17.9 ± 3.6	15.0 ± 2.8	10.4 ± 1.2	9.1 ± 0.7	8.7 ± 1.0
Total coliforms	(MPN/100 mL) × 1000 ± Std	3650 ± 1909	2900 ± 2500	2600 ± 565	950 ± 212	465 ± 245
Fecal coliforms	(MPN/100 mL) × 1000 ± Std	2000 ± 425	650 ± 26	215 ± 120	180 ± 56	6 ± 3
Flow	(L/s) ± Std	191 ± 31	171 ± 28	213 ± 42	181 ± 17	187 ± 22

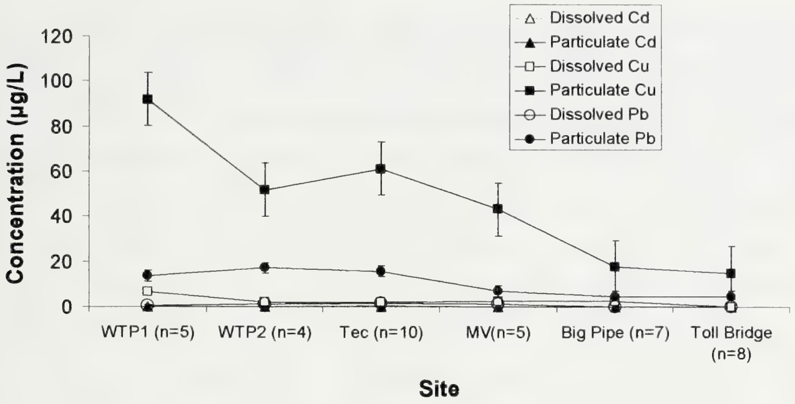

Fig. 2. Levels of dissolved and particulate cadmium (Cd), copper (Cu) and lead (Pb) in Tecate Creek/Alamar River; n denotes the number of samples taken at each site. Levels of disolved Cd are so low (<0.15 µg/L) that they do not show in the this figure.

of the organic and nutrient loads could be responsible for the appearance of some higher-demanding macroinvertebrate organisms especially at the last site on the Rio Alamar (Table 3).

Nitrification seems to be nearly totally absent, probably because of the high organic carbon levels in the water which leads to the dominance of heterotrophic bacteria and suppresses the development of nitrifying organisms (Table 4). Meanwhile, the decrease of total coliform densities remains moderate, with an 87% (110 × 10^3 MPN/100 mL km) removal efficiency; while fecal coliforms are reduced (69 × 10^3 MPN/100 mL km) with a rather high efficiency of 99.7%.

For most metals, there was a significant loss of the particulate (as well as the dissolved) fraction, as the water moved downstream in Tecate Creek to the Rio Alamar (Figures 2–3). Surprisingly, for Cu, Cr, and Ni, the highest levels observed among all of the sampled sites was actually at WTP1 (this site upstream of the discharge point for the Tecate Municipal Wastewater Treatment Plant), where levels of these metals were 98, 345, and 518 µg/L, respectively. It should be

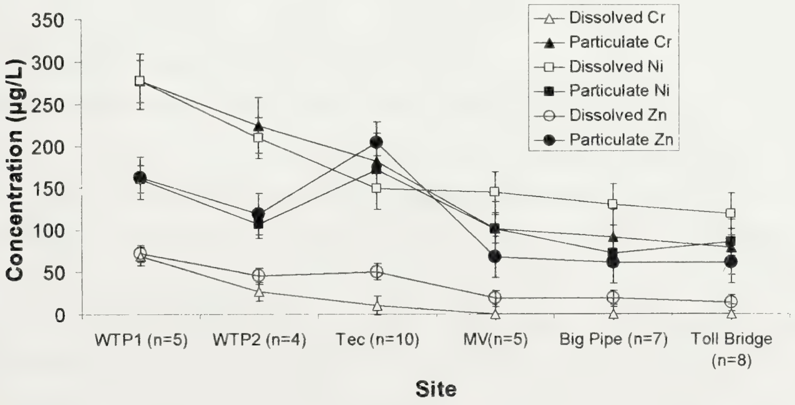

Fig. 3. Levels of dissolved and particulate chromium (Cr), nickel (Ni) and zinc (Pb) in Tecate Creek/Alamar River; n denotes the number of samples taken at each site.

noted here that this site (WTP1) lies just downstream of the point source discharge of water from a maquiladora (industrial) complex which includes a rather large metal-working facility. On three separate occasions in 2002, we sampled both upstream and downstream of the Wastewater Treatment Plant at WTP1 and WTP 2, respectively, and on one occasion, upstream and downstream of this specific maquiladora discharge point to Tecate Creek. The results of these analyses showed that the discharge from this industrial complex was a significant contributor to Tecate Creek's downstream metal contamination, and explained why observed levels were actually higher upstream of the Tecate Wastewater Treatment Plant for many of the metals we measured. Metal levels then generally decreased as the water moved downstream to the Toll Bridge site on the Rio Alamar, with total metal reduction efficiencies at the Toll Bridge (compared with WTP 2 upstream of the city of Tecate) of 71% for Cu, 60% for Cr, 76% for Pb, 40% for Ni, and 54% for Zn (Figures 2–3).

Discussion

Self-purification is a process which may allow the preservation of the ecological balance in a stream despite the presence of municipal sewage discharges upstream. It provides a unique set of advantages to clean-up polluted water streams: It acts very fast, does not require any chemical additions, acts instantly at the whole body of water at the site, works all the year around and can result in substantial decrease in contaminants concentration (Spellman 1996). Self-purification can be described as the sum of all physical, chemical, and biological processes by which the quantity of pollution in a stream is decreased. This self-purification results from mineralization of organic substances, nitrification-denitrification, sedimentation, and assimilation, as well as from dilution and mixing processes (Heidenwag et al. 2001).

Tecate Creek is excessively polluted with organic substances, plant nutrients, and fecal indicator bacteria because it receives the discharge of poorly-treated municipal sewage, brewery effluent, and industrial effluents containing heavy metals. The SIGNAL-w index (based on the occurrence of macroinvertebrate species) indicates an improvement from a grade of excessively polluted to only a grade of critically polluted over a flowing distance of 29 km to the downstream Rio Alamar site at Toll Bridge (Table 3), and this is confirmed by the results of chemical analyses (Table 4). Excessive pollution in this case, allows only the survival of the most tolerant macroinvertebrate species (most of them Diptera), while under conditions of critical pollution, more demanding organisms (e.g. Coleoptera, Odonata) can exist at least seasonally.

At first glance, this poor self-purification seems to be surprising because of a more or lesser natural stream morphology, relative good oxygen supply, and high water temperatures which should stimulate metabolism of bacteria. It should be noted here that temperature effects on self-purification were not investigated here, since other seasonal effects (e.g. flow rate, sunlight) complicate such an analysis. In a former study about Harz mountain streams in Germany (Heidenwag et al. 2001), we were able to show that self-purification concerning ammonium, phosphorus, organic substances, and bacteria can reach a rate up to 80% over a distance of only 2 or 3 kilometers in case of a natural stream morphology. Purification rates measured (118 mg/L km for COD; 45 mg/L km for BOD_5; 14 mg/L km for ammonia; 1.9 mg/L km for phosphorus) were one order of magnitude higher than in case of the Tecate Creek/Rio Alamar rates. However, these rates were only attained by a stream with a good ecomorphological structure, providing a high number of stable habitats with well developed biofilms, that contain aerobic layers for degradation of organic substances and nitrification (and also anaerobic layers for denitrification). Mikhailovski and Fisenko (2000) found under such conditions a still more rapid self-purification of a stream in the Toronto area. Unfortunately, rates for self-purification of streams in the southwestern United States have not been reported, since in this region sewage discharged to streams and rivers is at least secondary quality (and usually tertiary treated).

Horn (1992) and Horn and Hempel (1996), emphasize the outstanding role of biofilms in self-purification and especially in nitrification and denitrification. For this, bottom structure is the determining factor. Frey (2001) found that an increase of roughness leads to the strongest impacts on reduction rates and oxygen supply caused by the increment of flow duration and substrate surface for degradative and nitrifying bacteria. In Tecate Creek, the lack of appreciable nitrification activity is probably caused by the scarcity of these biofilms, as well as by the dominance of heterotrophic organisms that exist because of the high load of organic substances in the stream. Typically, in sewage-dominated effluents, nitrification does not occur until BOD levels become very low (Brehm and Meijering 1990; Jancarkova et al. 1997).

In Tecate Creek, solid inorganic surfaces are mostly absent, as are aquatic macrophytes. In lowland streams in Germany, self-purification performances remain lower than in mountain streams (Heidenwag et al. 2001), but macrophytes in such lowland streams can have there a comparable function as stones and rock debris in upland brooks, because their surface can be settled by periphyton. In Tecate Creek, there were only a few stable habitats, such as big rocks and bars covered with macrophytes, observed on the stream bottom. Even in the case of a (near)-pristine morphological structure, the features of a braided system like Tecate Creek, can set limits on the occurrence of such stable habitats on the stream bed because the sediment is constantly shifting in a natural manner. The resulting friction of the bottom substrate caused by the transposition of sediment in this braided system, may be responsible for the disturbed or missing biofilms.

The toxicity of metals may also strongly disturb the biotic community in streams (Schönborn 1992). The concentrations of heavy metals found in Tecate Creek are higher (except in the case of Cd) than those levels in freshwater found in natural streams all over the world (Schönborn 1992). However, our calculations (taking into account site-specific hardness values) show that for nearly all metals (except Ni), levels in Tecate Creek/Rio Alamar never exceeded either the CCC (criterion continuous concentration) which is a four-day average concentration chronic limit for metal pollutants in freshwater, or the CMC (criterion maximum concentration), a short-term concentration acute limit for metal pollutants not to be exceeded. Both of these water quality criteria provide for the protection of aquatic life from acute and chronic toxicity to animals and plants, and from bioconcentration by aquatic organisms (U.S. Environmental Protection Agency 2000). Even in the case of Ni, which was significantly elevated due to the discharge from a metal-working industrial plant upstream of the WTP2 site on Tecate Creek, the CMC value (1.51 mg/L) was never exceeded, and self purification lowered Ni levels, such that ambient water quality criteria were met (at all times tested) at all sites downstream of Marron Valley. Therefore, at least with regard to the metals we analyzed, toxicity effects to resident species would not be expected.

Conclusions

Our overall analysis shows that while little water quality benefit may be achieved by enhancing the ecomorphological status of Tecate Creek, the introduction of coarse material could help to enhance self-purification. The most immediate improvement in water quality status could be achieved by controlling the discharge of organic pollution from the waste treatment plant and the brewery. This could be done by means of technical sewage treatment systems or with subsurface flow constructed wetlands which are cheaper and more stable in function (Lüderitz et al. 2001). In the nearly unsettled area between Tecate and Tijuana a cascade of such wetlands consisting of relatively coarse and stable material could be constructed with moderate efforts. Further research and development is going on to estimate the necessary dimensions of such systems. Self-purification can support such activities but it would not be able to replace them.

Acknowledgments

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Age and Growth of Spotted Sand Bass, *Paralabrax maculatofasciatus,* in Bahia de Los Angeles, Baja California, Mexico, with Age Validation using Otolith Edge Analysis

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Abstract.—Spotted sand bass, *Paralabrax maculatofasciatus,* were collected from Bahia de Los Angeles, Baja California, Mexico covering as wide a size range as possible over four seasons (spring, summer, fall, and winter). Age was estimated and growth parameters calculated from growth zones counted in transverse otolith sections. An otolith edge analysis indicated an opaque growth zone was deposited once per year during the summer, validating the annual periodicity. Spotted sand bass from this region are fast growing with a relatively short life span of up to 11 years. Growth differs from the disjunct Pacific coast population by having a higher growth rate and a shorter longevity.

Introduction

Spotted sand bass, *Paralabrax maculatofasciatus,* are a common nearshore fish ranging from Mazatlan, Mexico, into the Gulf of California, and north to Monterey Bay, California (Miller and Lea 1972). One collection in the late 1800's placed this species as far north as San Francisco, California, but it is more common in warmer waters and is rarely encountered north of Newport Bay in southern California (Love 1996). The ecology and life history of spotted sand bass off southern California and the northern Baja California coast is well documented (Butler et al. 1982; Oda et al. 1993; Allen 1985; Allen et al. 1995; Hovey and Allen 2000; Bocanegra-Castillo et al. 2002) and less is known for the disjunct population of the northern Gulf of California (Hastings 1989; Ferry et al. 1997). Age and growth characteristics of spotted sand bass have been described and validated for the southern California population (Allen et al. 1995), but have not been described for the Gulf of California population.

There are two disjunct populations of spotted sand bass in the eastern Pacific Ocean; 1) those found along the Pacific coast of California and northern Baja California, and 2) those in the northern Gulf of California. On a geological time scale these populations were probably joined into a single larger population before being separated by the Baja Peninsula due to oceanographic and geologic processes (Case et al. 2002). Warm water temperatures at the tip of the Baja California Peninsula seem to preclude movement of spotted sand bass between the two populations, as is evidenced by the genetic divergence of the two populations

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(Tranah and Allen 1999; Stepien et al. 2001); hence, growth characteristics may be different from the Pacific coast populations.

The objectives of this study were to: 1) estimate the age and growth characteristics of spotted sand bass from Bahia de Los Angeles in the northern Gulf of California by counting growth zones in transverse otolith sections, 2) validate the annual periodicity of growth zone formation by performing a seasonal edge analysis, and 3) compare growth characteristics of the Gulf of California population with the characteristics described for the southern California spotted sand bass (Allen et al. 1995).

Materials and Methods

Spotted sand bass were collected in and around Bahia de Los Angeles, Baja California, Mexico (Figure 1). Collection methods consisted of hook-and-line, Hawaiian sling pole spears, and beach seining. Fish were collected mid-season, approximately 3 months apart, over several years (1992, 1994, and 1995). Sampling events were designated as seasonal by collection dates and categorized as spring, summer, fall, or winter (Table 1). Sampling efforts were focused within each season to collect fish covering as much of the full size range as possible and under-represented length classes were targeted as sizes became well represented; a sample size of approximately 20 fish per 10 mm length class was considered adequate. We targeted different length classes by selecting size appropriate gear (e.g hook size, pole spears, beach seine) and sampling location and depth. The parameters of weight (g) and standard length (SL, mm) were recorded for each fish collected. Both sagittal otoliths were extracted, cleaned, labeled, and stored dry. Sex determination was not attempted because the northern Gulf of California population of spotted sand bass is known to exhibit protogynous hermaphroditism (Hastings 1989; Hovey and Allen 2000).

Fish ages were estimated from transverse sagittal otolith sections mounted on microscope slides and viewed under a dissecting microscope with transmitted light. Transverse sections containing the nucleus were removed using a Buehler® Isomet low-speed bone saw with two Norton® low-density diamond blades separated by acetate spacers (0.6 mm). Sections were placed on a slide and mounted with Cytoseal™ epoxy. Sections were thinned and polished to optimal viewing thickness using a Buehler® Ecomet III lapping wheel with 600 grit silicon carbide, wet/dry sandpaper.

Ageing criteria were based on well-defined growth zones (Figure 2). The sulcal region exhibited the clearest growth zones for ageing and was the region used to count annuli. Otolith sections with growth zones that could not be counted were disregarded. Young-of-the-year (YOY) fish that had not formed the first opaque zone were aged as zero years because they had not completed the first year's growth. Thereafter, the formation of each opaque growth zone was interpreted to represent a single year's growth.

Edge analysis was performed on the transverse sections of all aged otolith sections. Edge types were defined as translucent or opaque to transmitted light. The otolith section was not considered for edge analysis if the edge type could not be resolved. Validity of the annual age estimates was based on whether there was a seasonal formation of the opaque growth zone. Three readers independently aged readable otoliths three times each. Otolith readers consulted with each other

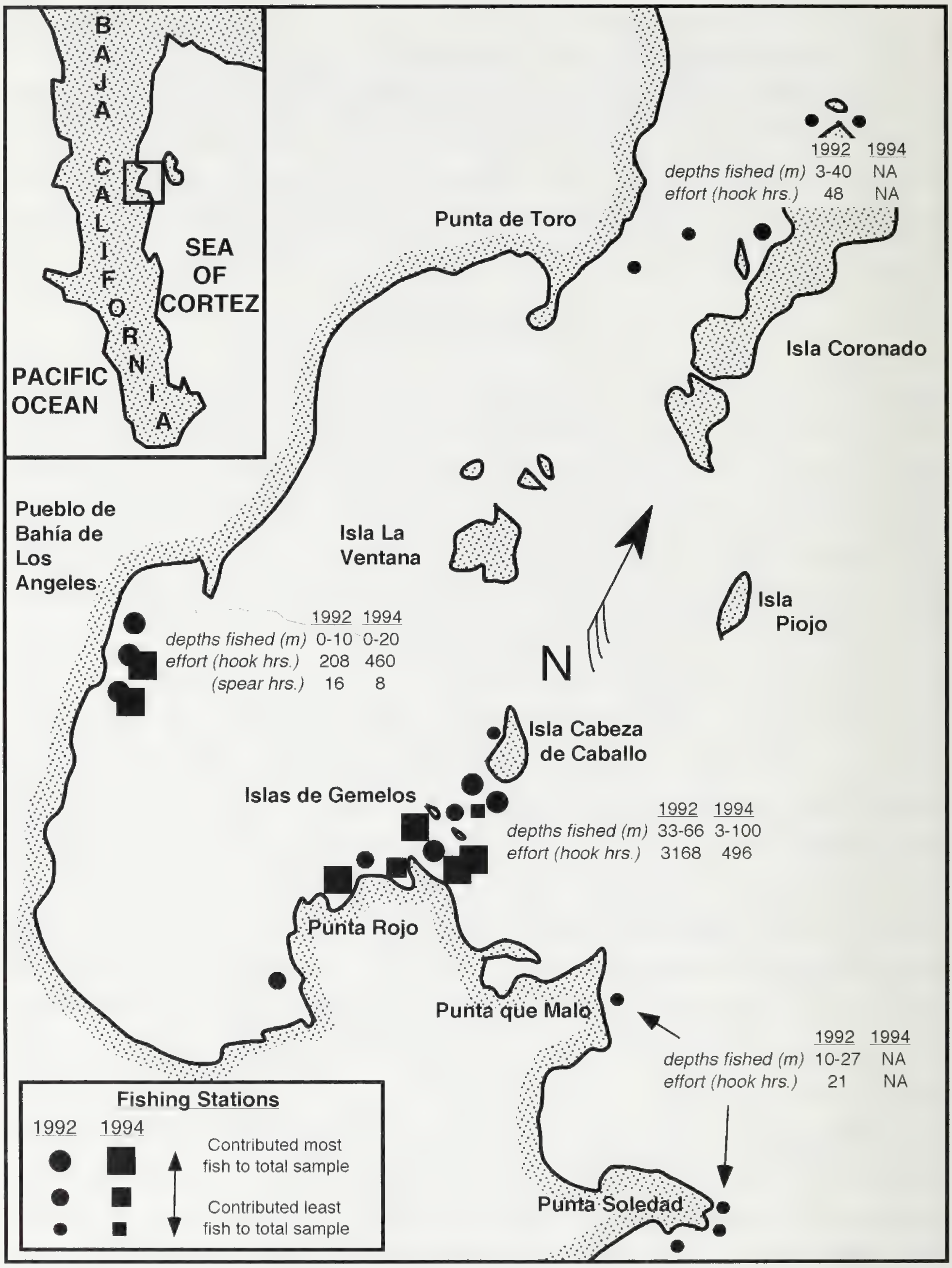
BAJA CALIFORNIA
SEA OF CORTEZ
PACIFIC OCEAN
1992 1994
depths fished (m) 3-40 NA
effort (hook hrs.) 48 NA
Punta de Toro
Isla Coronado
Pueblo de Bahía de Los Angeles
Isla La Ventana
Isla Piojo
N
1992 1994
depths fished (m) 0-10 0-20
effort (hook hrs.) 208 460
(spear hrs.) 16 8
Isla Cabeza de Caballo
Islas de Gemelos
1992 1994
depths fished (m) 33-66 3-100
effort (hook hrs.) 3168 496
Punta Rojo
Punta que Malo
1992 1994
depths fished (m) 10-27 NA
effort (hook hrs.) 21 NA
Punta Soledad
Fishing Stations
1992 1994
Contributed most fish to total sample
Contributed least fish to total sample

Fig. 1. Map of the Bahia de Los Angeles region with sites sampled and sampling effort. Samples taken in 1995 were from a fisherman at the beach in Bahia de Los Angeles (summer) and from locations intermingled with the sites near town and Punta Rojo (winter).

Table 1. Definition of season category based on collection dates.

Season	Dates of collection
Spring	27 March to 2 April 1994
Summer	12 to 21 July 1994, and 1 to 15 July 1995
Fall	15 to 23 October 1992
Winter	9 to 20 January 1995

to set criteria for counts and to resolve differences. Otoliths that did not meet agreed upon criteria were disregarded. Average percent error (APE) and index of precision (D) were calculated to assess variability of age estimation within and between readers (Chang 1982; Campana 2001). A von Bertalanffy growth function was calculated from estimates of age and fish length using FISHPARM software. An allometry growth function was also estimated for the relationship of fish weight and length to describe somatic growth. An estimate of longevity was calculated using the exponential nature of the von Bertalanffy equation, where 95% longevity (yr) = 5 ln(2)/*k* (H. Mollet, Pacific Shark Research Center, Moss Landing Marine Laboratories, personal communication), and *k* represents the growth coefficient.

The growth rate estimated from our study was compared to the growth from data analyzed by Allen et al. (1995). This latter study assumed an age of six months (0.5 yr) for YOY, differing from our assumption of age zero for YOY. To compare growth between the two studies, Allen et al. (1995) provided their data and we adjusted it to match our criteria. Length at age data was log-transformed for both data sets. Calculated growth rates (slopes) were compared between the Pacific coast and Gulf of California populations using an analysis of covariance (ANCOVA). In particular, the ANCOVA will determine if the slopes of these lines are parallel (i.e. if fish in these populations grow at the same rate). Prior to testing for differences between the Gulf and Pacific coast populations,

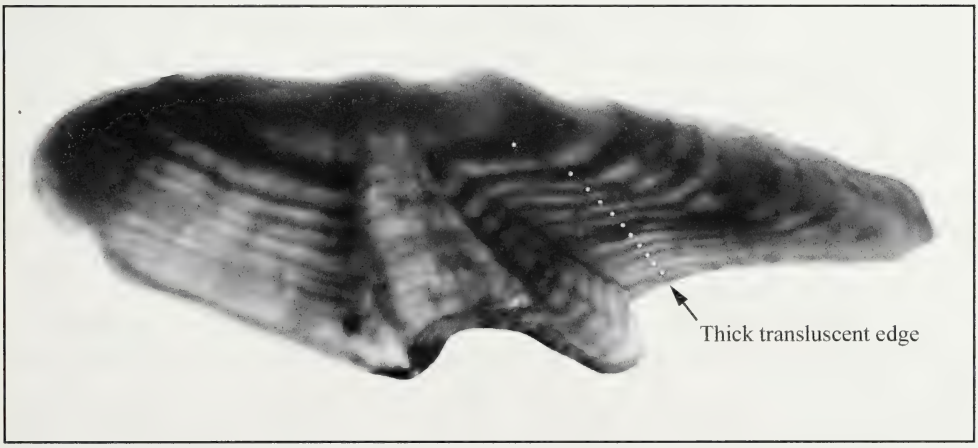

Fig. 2. Image of the transverse otolith section from the oldest aged fish. Age from growth zone counts was 11 years and is denoted with a small white spot on each counted annulus. Note that this fish was collected in the Spring and that the section has a thick translucent edge (the dark edge is an edge-effect artifact of the transmitted light).

Table 2. Collection season and year with length and weight ranges and the number of fish collected for each sampling period.

Season	Length range (mm SL)	Weight range (g)	Sample size (*n*)
Spring (1994)	32–322	5–750	169
Summer (1994)	85–320	15–860	76
Summer (1995)	125–264	n/a	18
Fall (1992)	56–307	14–709	269
Winter (1995)	69–300	5–760	72

ancillary data for three small fish collections made north of Bahia de Los Angeles (Los Pulpos, Puertocitos, and Gonzaga Bay) were analyzed in the same manner to investigate potential growth differences in other parts of the northern Gulf (Larry Allen, CSU Northridge, unpublished data).

Results

Six hundred and four spotted sand bass were collected from various nearshore and island locations in Bahia de Los Angeles, Baja California, Mexico. Most were captured using hook-and-line over bottom depths of 6–45 m. The smallest specimens were collected in spring 1994 with a beach seine in shallow water over a sandy bottom. Specimens collected using pole spears were gathered in 1–10 m of water at the rock-sand interface.

During each season, the collection effort, length and weight ranges, and the number of fish caught differed (Table 2). The majority of the specimens (approximately 45%) were collected in fall 1992. The smallest (32 mm SL, 14 g) and the largest (322 mm SL, 750 g) fish were collected in spring 1994. The narrowest fish length range (125–264 mm SL) and fewest fish (N = 18) were collected in summer 1994. Size and age frequency histograms were not constructed because of the size-targeted nature of the sampling effort, resulting in the release of many fish with lengths for which sampling was sufficient. Furthermore, gear selection bias could not be corrected (e.g., selecting hook size to target smaller or larger fish, net mesh on beach seine, difficulty targeting small fish with pole spears, etc.).

An allometric equation adequately described the length-weight relationship for 554 of the spotted sand bass collected ($R^2 = 0.956$, Figure 3). The heaviest fish collected (860 g) was also one of the longest (320 mm SL). The six fish that weighed greater that 700 g were not the oldest and ranged from 3–7 yr. The oldest fish (11 yr) weighed 525 g and was 308 mm SL.

Two otolith readers aged 556 spotted sand bass from the Gulf of California, of which 508 were deemed readable by both readers, and estimated age ranged from 0 yr for YOY to 11 yr (Table 3). Otoliths were easy to read and age estimates were very repeatable, as was evidenced by the 93% agreement between readers. Few readings deviated by more than 1 year and age differences were never more than 2 years. Reader disagreement was very low as was indicated by an APE and D of 1.4%, and a CV of 2.0%. Young-of-the-year fish were collected in all seasons except summer. The widest range of age estimates came from the spring 1994

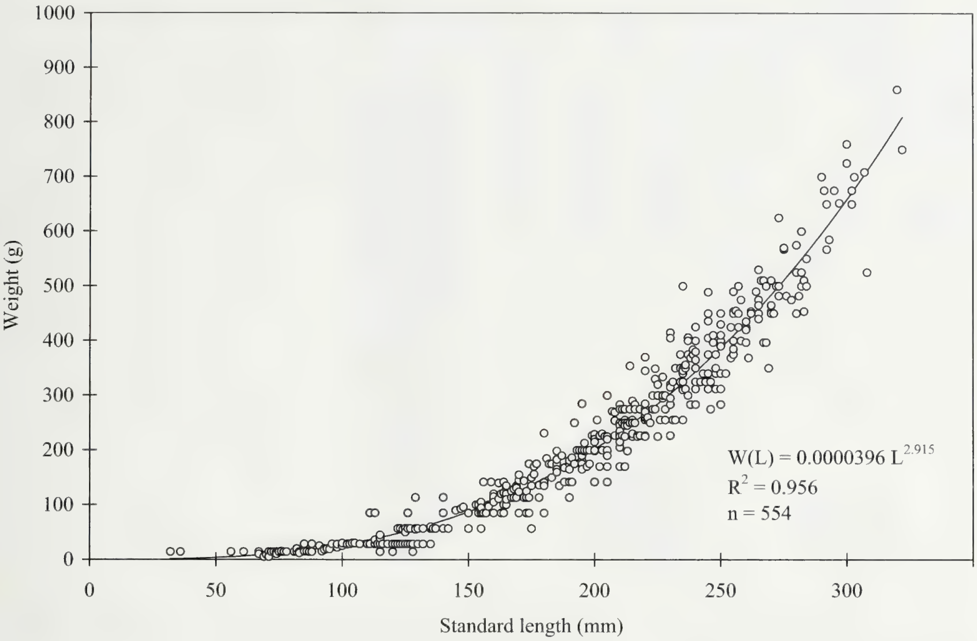

Fig. 3. Plot of a logistic growth function fitted to the weight and length of the fish collected.

samples. A minimum of about 60% of the age range observed was collected during any season.

A von Bertalanffy growth function (VBGF) was fitted to the age estimates (Figure 4). The fit was good (R^2 = 0.827) and the VBGF indicated the growth rate was relatively high (k = 0.296 ± 7.3%) with a predicted maximum size (L_∞) of 300 ± 2.5% mm SL. Based on the exponential nature of the von Bertalanffy function, 95% longevity is about 12 yr.

Readers identified edge types as either translucent or opaque. Agreement between readers for edge type was 90%. Disagreement was highest for summer and fall (16%) and 2 to 3% for spring and winter. For sections where disagreement on edge type was irresolvable, the section was removed from consideration, resulting in a total of 499 otolith sections used in the edge analysis. Irresolvable edge type was typically for sections that were not the best quality and with older aged fish; determining edge type for older sections was usually the most difficult because the growth zones were more compressed. The greatest incidence of oto-

Table 3. Age ranges and number of spotted sand bass aged from each sampling season in the Gulf of California.

Season	Age estimates (yr)	Sample size (*n*)
Spring (1994)	0–11	164
Summer (1994)	1–7	73
Summer (1995)	1–7	15
Fall (1992)	0–10	236
Winter (1995)	0–6	68

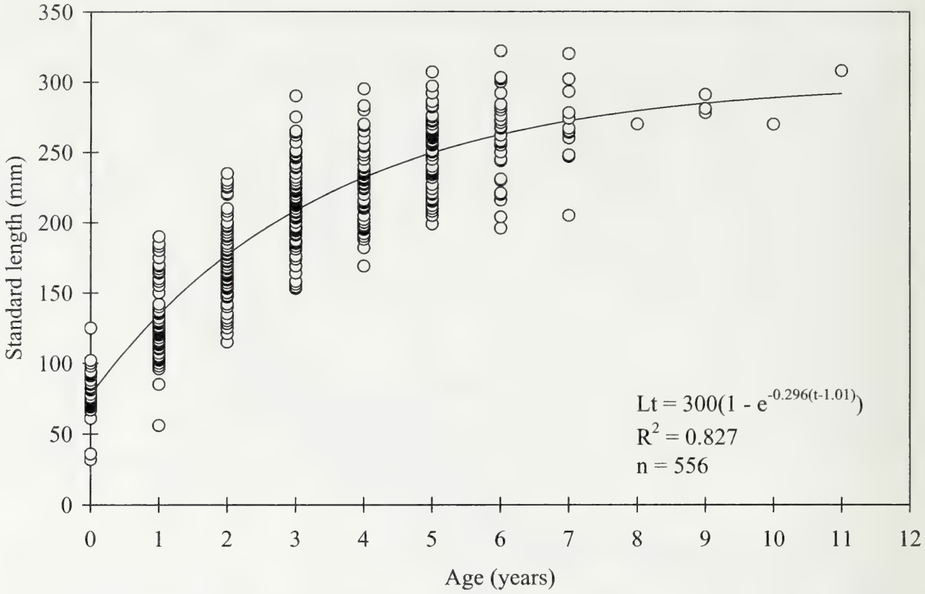

Fig. 4. Plot of the von Bertalanffy growth function fitted to the length and age data for spotted sand bass. Note the considerable variation in size with age and that some fish grow very quickly, some approaching 200 mm SL bay and age of 1 yr.

liths with opaque edges occurred in samples collected during summer periods (83%; Figure 5). Edges of spotted sand bass otoliths from the other three seasons were mostly translucent (84–95%).

The ANCOVA indicated that growth rates within the northern Gulf were not significantly different ($p = 0.340$), but did differ for the Pacific coast population ($p<0.001$, Figure 6). Hence, spotted sand bass grow faster in the Gulf of California than they do in Pacific coast waters. Log-linearized growth rates can be translated into a rate of mm/year. Fish in the Gulf population are growing at an average rate of ca. 27 mm/year, whereas the Pacific coast population are growing at an average rate of ca. 10 mm/year; less than half that of the Gulf population.

Discussion

Spotted sand bass are one of the most common nearshore fishes in Bahia de Los Angeles and were readily caught in every season except winter. During winter sampling they were uncommon and skittish at free diving depths (<10 m), and were either not biting or not present at fishing sites where they were abundant in the other three seasons. Fishing at greater depths (30–45 m) led to more frequent encounters with gold spotted rock bass (*P. auroguttatus*) in all seasons (Pondella et al. 2001). One marked exception was an aggregation of large spotted sand bass over sand at the mouth of a small cove near deep water (>50 m) at the southern entrance to Bahia de Los Angeles. These large adults (210–295 mm SL) readily took bare hooks and seemed to be exhibiting an aggregational behavior similar to that observed in Southern California waters (Larry Allen, CSU Northridge, personal communication).

Spotted sand bass from Bahia de Los Angeles did not differ in growth from

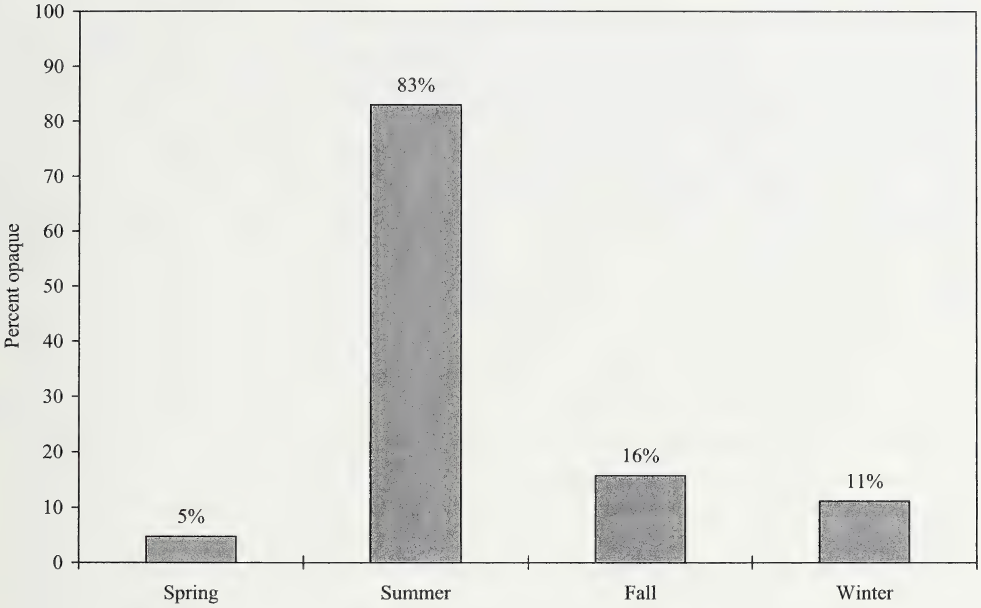

Fig. 5. Frequency histogram of edge type determined from transverse otolith cross sections. A total of 499 otoliths were used in the edge analysis (Spring n = 161, Summer n = 74, Fall n = 198, Winter n = 66). The percentage of opaque edge type is given on top of the bars for each respective season.

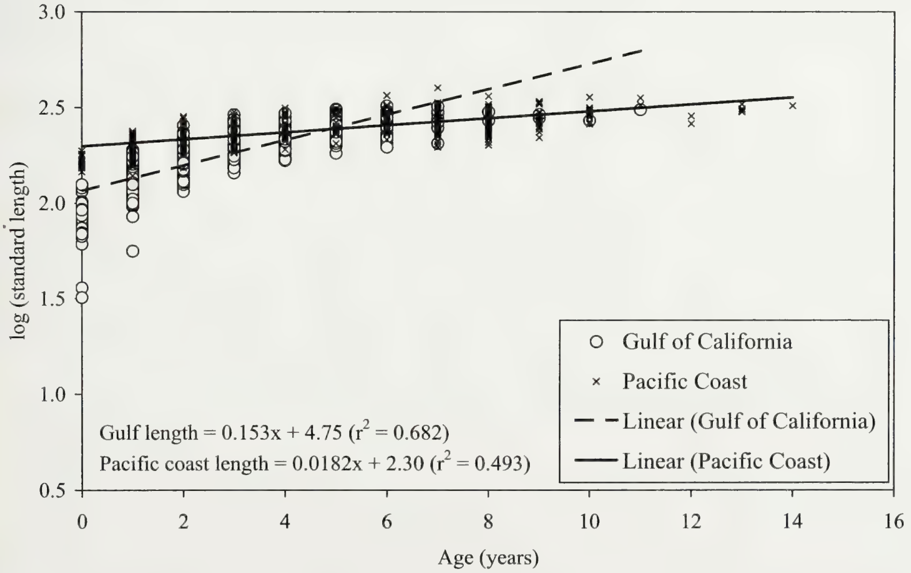

Fig. 6. Plot of log-linearized standard length and age for the Pacific coast population (Allen et al. 1995) and the Bahia de Los Angeles population with the corresponding regressions used to calculate growth trajectories.

fish collected further north in the Gulf, but this finding must be qualified by the low samples size and limited size range of these collections. To further check for differences we added the aged fish to the VBGF data from Bahia de Los Angeles to see if it changed the parameters to any extent that could be considered significant. The criteria used was the 95% confidence interval for the VBGF parameters. The growth coefficient (k) decreased slightly to 0.256 ± 7.7% and the asymptotic length (L_∞) increased slightly to 314 ± 2.9% mm SL. Neither changed significantly in this rather subjective test and we concluded that growth in the northern Gulf is probably similar throughout the region.

The growth trajectory of spotted sand bass in Bahia de Los Angeles differs from that of the Pacific coast populations as well as its congeners. Specifically, spotted sand bass in the northern Gulf grow faster than those found in Pacific coast populations, contrasting greatly in terms of the growth coefficient (>0.25 vs 0.1077; Allen et al. 1995). This is also much higher than that of its longer-lived congeners, kelp bass (*P. clathratus, k* = 0.06; Love et al. 1996), barred sand bass (*P. nebulifer, k* = 0.08; Love et al. 1996), and golden spotted rock bass (*P. auroguttatus, k* = 0.115; Pondella et al. 2001). In addition, this growth rate is more typical of tropical serranids and resides among the faster growing fishes (e.g. Manooch 1987). In this study, some one year old fish had reached nearly 200 mm SL and some had exceeded this length by their second year. The relatively high growth rate described in this study is driven by the small fish collected from Bahia de Los Angeles coupled with growth to large size within the first few years, and its relatively short longevity (11–12 yr).

It is possible that larger, and presumably older, fish were missed in Bahia de Los Angeles despite our collection efforts. A maximum length of 559 mm total length (TL; ca. 500 mm SL) is given for spotted sand bass (Thomson et al. 1979). This is much larger, however, than any specimen reported here or by Allen et al. (1995). A follow up communication about the source of the high maximum length revealed that there was no support for the claim (Lloyd Findley, CIAD-Unidad Guaymas, personal communication). As a result, the maximum length of spotted sand bass in the Gulf of California was reduced to a substantiated 381 mm TL (ca. 336 mm SL) in the revised edition of *Reef Fishes of the Sea of Cortez* (Thomson et al. 2000).

The length-weight relationship, when considered with respective ages, is useful in describing the variability of growth for this species. Spotted sand bass can become large fish in a relatively short period of time, while smaller fish can be considerably older than the largest fish. In this study, the oldest fish was a low weight individual with a length close to the longest fish (525 g at 308 mm SL). This fish seems atypical of the Bahia de Los Angeles population. The largest fish, those with the greatest weights and lengths, had low to average ages (3–7 yr). The largest individual in this study weighed only half as much as the largest spotted sand bass taken in the southern California population (>1800 g at 400 mm SL; Allen et al. 1995). While the differences in size and age between the Pacific population and the Gulf population can be explained by the disjunct distribution of the species (Trahan and Allen 1999), the plasticity of size and age within the population is a bit of a mystery. It may be explained by localized habitat variability, timing of oceanic events, or competition to broadly qualify a few factors. The oldest fish not being the largest or heaviest fish, however, is becoming a relatively common observation in fishes (e.g. rockfishes, Cailliet et al. 2001).

Despite the limited temporal resolution of a seasonal application of the edge analysis, the results indicate the annual interpretation of growth zones in otolith sections is valid for spotted sand bass in Bahia de Los Angeles. Sampling once per month over a period of one year would have been optimal (Campana 2001), but the remote nature of Bahia de Los Angeles precluded this kind of sampling design. Based on the seasonal sampling, it is clear that an opaque growth zone is formed once a year over the summer months with a low probability of the opaque zones forming in any other season. The other northern Gulf collections made at a time that corresponds with our Spring collections had a low incidence of opaque zone formation (13%); it is interesting to note that the Gonzaga Bay collections had the highest incidence of early opaque zone formation (24%, n = 46). In addition, the timing of opaque zone formation is in agreement with the findings for the Pacific coast populations (Allen et al. 1995).

Spotted sand bass in the Bahia de Los Angeles region are fast growing fish that can attain an age of about 11 yr, a length of about 320 mm SL, and a weight of at least 820 g. In Bahia de Los Angeles they grow faster than fish in the southern California population, but attain a smaller maximum size and a younger maximum age (Allen et al. 1995). The average annual water temperature of Bahia de Los Angeles is higher and has a much greater range than is recorded for the southern California environment (Tranah and Allen 1999). Specific to the Bahia de Los Angeles region, a strong seasonal upwelling is induced by high wind and current speeds in the Canal de Ballenas, just outside the bay, coupled with the rugged island bathymetry. As a result of the upwelling conditions, Bahia de Los Angeles is one of the most productive regions in the Gulf of California (Thomson et al. 2000, Case et al. 2002). It is likely that temperature differences, coupled with the high seasonal productivity, explain the observed growth trajectory differences between the two populations.

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Feeding Ecology of Salton Sea Tilapia (*Oreochromis* spp.)

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Abstract.—We investigated the feeding ecology of tilapia (*Oreochromis* spp) in the Salton Sea. Stomachs and intestines were sampled at each season. Fish foraged at the surface during the summer when dissolved oxygen was low. The proportion of plant materials in fish stomachs was higher at river mouth areas. Diatoms dominated the phytoplankton; rotifers were dominant during the spring and summer; copepods were dominant during the fall; barnacle larvae dominant during the winter. Pile worms (*Neanthes succinea*) were present throughout the year. Feeding activity was reduced in the summer, when dissolved oxygen was low and water temperature high.

Intra-specific feeding plasticity is widely recognized in fishes (Wooton 1998) and is a function of environmental factors (Fryer and Iles 1969). Feeding strategies of cichlids are diverse and highly adapted to exploit a variety of niches (Fryer and Iles 1972; Maitipe and De Silva, 1985; Bowen and Allanson 1982). Tilapia are the most widely distributed exotic fish worldwide (Lowe-McConnell 1975; Bowen and Allanson 1982) because of their importance in aquaculture (Costa-Pierce and Rakocy 1997, 2000). The success of tilapia invasions is in part due to their ability to respond quickly to environmental changes by varying life history traits (Bruton and Allanson 1974; Noakes and Balon 1982) and exploiting multiple trophic levels (Fryer and Iles, 1969; Bowen, 1982).

Feeding patterns in the Mozambique tilapia (*O. mossambicus*) may be a function of ontogeny and environment (Bowen and Allanson 1982). Mozambique tilapia in Lake Sibaya, South Africa, are known to be detritivorous and inhabit shallow areas in the juvenile phase and deep areas during adulthood (Brutton and Boltt 1975; Bowen 1979). Juvenile tilapia select the inshore areas in Lake Sibaya to seek refuge from predators (Bowen and Allanson 1982) and to take advantage of the more nutritious detrital aggregate (Bowen 1979). The Mozambique tilapia also has the ability to feed on plants and algae (Maitipe and De Silva 1985; Bowen 1982; DeSilva et al. 1984; Khallaf and Alme-na-ei 1987; Beveridge and McAndrew 2000). Mozambique tilapia can digest cellulose in addition to microbial and particulate matter in sediments due to high stomach acidity, which may reach a pH of less than 1 (Dempster et al. 1995). Tilapia have also been known to feed selectively on animal matter (De Silva et al. 1984).

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The Salton Sea is a 980 km^2, closed basin salt lake in the Sonoran Desert of southeastern California. The high salinity (44 g/L) and frequent wind-driven summer deoxygenation events of the lake make it an extreme environment conducive to unique behavioral adaptations in fish. Over 70 species of marine fish have been introduced starting in 1929 (Walker et al. 1961) and over 30 species have been introduced in major numbers (more than 50 fish). Major introductions were done between 1950 and 1956 into the Salton Sea from Mexico's Gulf of California (Walker et al. 1961) from which the orangemouth corvina (*Cynoscion xanthulus,* Jordan and Gilbert), Gulf croaker (*Bairdiella icistia,* Jordan and Gilbert) and sargo (*Anisotremus davidsoni,* Steindachner) established and flourished. During the late 1960s a hybrid tilapia (*Oreochromis mossambicus* Linnaeus × *O. urolepis hornorum* Linnaeus) invaded the lake (Costa-Pierce and Doyle, 1997) and became the dominant species (Costa-Pierce and Riedel 2000; Riedel *et al.* 2002).

Because the Salton Sea tilapia have higher growth rates than conspecifics in other systems (Riedel *et al.* 2002), nutritional constraints may not exist. Riedel *et al.* (2002) show evidence that the Salton Sea is a productive lake for tilapia, despite high summer water temperatures (over 32°C), frequent wind-driven anoxia over large areas, and high salinities. We investigated the feeding of Salton Sea tilapia to determine the possible reason for the high tilapia growth rates and production in the Salton Sea and to describe tilapia feeding ecology in this stressful environment.

Methods

Tilapia feeding was investigated by measuring stomach acidity, verifying the color of intestinal material, and determining stomach contents and fullness. Plankton samples were taken at the Salton Sea during the summer, spring, and winter to provide an estimate of food availability for tilapia. One hundred and fifty two fish were collected in the spring (43 fish), summer (38 fish), fall (38 fish), and winter (33 fish) from five stations at river mouth, nearshore, and pelagic areas (Figure 1) to assess feeding patterns according to seasons and sampling areas. Fish collections were done with multipanel, multimesh gill nets and plankton collections with a 40 μm mesh net.

Stomach acidity was measured at all seasons with an Orion micro-combination pH glass electrode model 9802BN. The acidity from the upper, mid, and lower sections of the stomach was measured within 1 h of capture from five randomly selected fish at all stations. After the measurements, all stomach contents were transferred to glass vials containing 10% buffered formalin and given a unique identification code. Stomach contents and plankton samples were filtered out of the formalin solution in laboratory using a 40 μm mesh and transferred to 75% ethanol. Stomach fullness was estimated from the difference between the weight of the full and empty stomach. At one station only (Figure 1), one gillnet was set for one hour at dawn, mid-morning, mid-afternoon, dusk, and night to investigate diel cycles in feeding, using stomach acidity as a proxy.

The color of the intestinal contents was determined within 3 h of capture to estimate the degree of food assimilation of ingested material (Moriarty 1973). Intestinal material was identified as either green, indicating poor assimilation, or

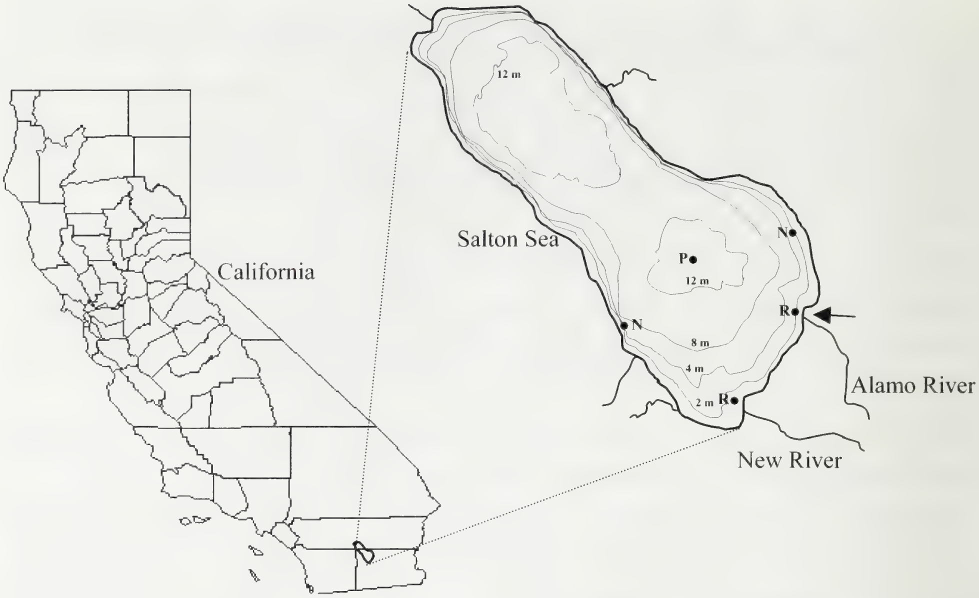

Fig. 1. Sampling sites at the Salton Sea. R—river mouth; N—nearshore; P—pelagic. Arrow indicates station where data were collected for assessing diel patterns in tilapia stomach acidity.

brown, for well assimilated food. No identification of organisms from intestines was attempted because of the advanced stage of digestion.

Stomach contents were grouped into sediment, plant material (macrophytes only), and Salton Sea biota. Sediment comprised sand, clay, and microbial organisms (not identified) and was used as a surrogate for determining foraging location within the water column. Macrophytes drift into the Salton Sea from land via the incoming tributaries. Marcophytes were considered because they are a potentially important tilapia food source, especially in the river mouth area. Salton Sea taxa were grouped further into benthos, zooplankton, and phytoplankton. Zooplankton were barnacles (planktonic stages of *Balanus amphitrite*), copepods (mostly *Cyclopods* spp), and rotifers (mostly *Brachionus* spp). Nematodes (mostly *Spilophorella* spp), ciliates, and pile worms (*Neanthes succinea*) were the benthic group. Phytoplankton consisted of dinoflagelates and diatoms. Groups of organisms other than the above were observed, but not analyzed due to low (< 1%) frequency of occurrence. Percentages based on numbers of organisms within taxa were defined for analyses within those groups for each stomach. Analyses of seasonal and spatial variation in feeding were done independently for all groups.

Percentages within taxa were averaged over individual fish to show taxa relative abundances according to space and season. Percentages, therefore, did not necessarily add to 100%. As a hypothetical example, if one fish had 100% of diatoms and another an empty stomach, the stomach content proportion was 50% diatoms for both fish taken together. The same rationale applies to proportions within groups. Because we report proportions of numbers, the often large abundance of phytoplankton would overwhelm all other taxa if no grouping was defined, overestimating the importance of abundant taxa and possibly precluding analyses for other groups of organisms.

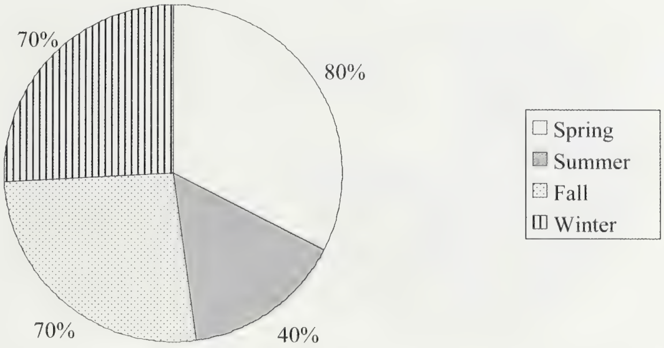

Fig. 2. Mean percentages of ingested sediment over all stations by season present in tilapia stomachs sampled at the Salton Sea. Spring n = 43, summer n = 38, fall n = 38, winter n = 33. Mean values were calculated from individual stomachs.

Because of heteroskedasticity in the data, proportions were analyzed using distribution-free statistical methods. Sediment and Salton Sea biota groups were analyzed for seasonal and spatial patterns. Kruskal-Wallis tests (Sheskin 2000) were used to assess seasonal and spatial patterns in feeding. Macrophytes were analyzed for spatial patterns only. The average percent of zooplankton in tilapia stomachs was compared with the percentages of taxa in plankton tows using a chi-square goodness-of-fit test (Sokal and Rohlf 1995) to estimate feeding electivity. Only barnacles, copepods, and rotifers were used because of the low occurrences of other taxa. Percent occurrence from plankton tows were the estimate for the expected value and the percentages from tilapia stomachs were the estimate for the observed value when conducting the chi-square test.

Feeding activity was estimated from the average acidity of the upper, mid, and lower section of each stomach (Moriarty 1973). A one-way analysis of variance (ANOVA) with color of intestinal material as the factor was used to assess the effect of stomach acidity on food assimilation. Diel and seasonal feeding activity was examined with a split-plot ANOVA (Winer *et al.* 1991), with time of day as the within factor and season as the between factor.

Results

The sediment proportion in stomachs was lowest during the summer (Figure 2; Kruskal-Wallis test statistic = 40.6, $p < 0.01$, 3 df). Macrophyte proportions were highest in river mouth areas (Figure 3; Kruskal-Wallis test statistic = 8.5, $p = 0.01$, 2 df). Diatoms were the dominant phytoplankton in the stomachs at all seasons and sampling areas. Diatom abundance was highest in the winter and spring and dinoflagellates highest in the spring (Table 1; Kruskal-Wallis test statistic = 14.3, $p < 0.01$, 3 df). Neither dinoflagellates nor diatoms varied in abundance according to sampling area.

The proportions of rotifers, copepods, and barnacles in stomachs varied with season (Figure 4; Kruskal-Wallis test statistic = 45.3 (barnacles), 74.0 (copepods), and 73.4 (rotifers), $p < 0.01$, 3 df). Rotifers were most common in the spring, copepods in the summer, and barnacles in the winter (Figure 4; Table 1). There was no evidence of a spatial pattern for either group. Chi-square tests indicated that there was no difference between the expected plankton percentages (plankton

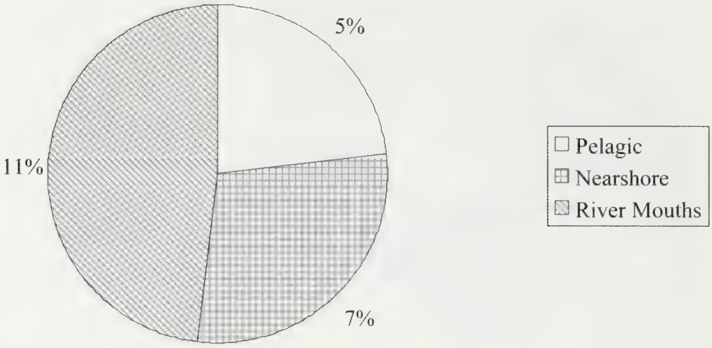

Fig. 3. Average percentages of ingested macrophytes by sampling area present in tilapia stomachs sampled at the Salton Sea. Pelagic n = 11, nearshore n = 32, river mouth n = 109. Mean values were calculated from individual stomachs.

tows) and the observed plankton percentages (tilapia stomachs) for barnacles, copepods, and rotifers during the summer ($p > 0.1$), fall ($p > 0.1$), and winter ($p > 0.1$; Figure 5).

Pile worms and nematodes were highest in the spring and fall (Table 1; Kruskal-Wallis test statistic = 11.1, $p = 0.01$ (pile worms), 29.6, $p < 0.01$ (nematodes), 3 df). Ciliates were highest during the summer (Kruskal-Wallis test statistic = 7.0, $p < 0.01$, 3 df). Pile worms in stomachs were more abundant at the river mouths (Table 1; Kruskal-Wallis test statistic = 7.0, $p = 0.03$, 2 df).

There was no pattern between intestinal color and stomach acidity nor was there evidence of stomach acidity varying according to time of day. Fisher's LSD post-hoc groupings were spring-summer and fall-winter (Figure 6). Stomach acidities were lower during the fall-winter period compared with the spring-summer period (Figure 6; split-plot ANOVA, $p = 0.02$ for factor season, 104 error df).

Discussion

Our observations show that the summer at the Salton Sea is a stressful period for tilapia. We commonly observed tilapia in the summer gulping air for oxygen and spending most of their time at the surface (Costa-Pierce and Riedel 2000; Riedel *et al.* 2002). Water temperature often surpasses 32°C and oxygen intermittently drops to zero over large areas during that season. We do not, however, exclude the winter from also being a stressful period for tilapia because water temperatures during winter may drop to their minimum lethal limit (Costa-Pierce and Riedel 2000).

The seasonal variation of the sediment quantity in tilapia stomachs indicates that fish spend the least amount of time foraging at the bottom during the summer. The presence of sediment in tilapia stomachs during the summer is indicative that fish can use detritus, despite anoxia at the bottom. Salton Sea tilapia in the summer may venture to the bottom to feed on detritus in the nearshore and quickly return to the surface for oxygen. Tilapia move toward the shore during warm months (Riedel and Costa-Pierce 2002; Costa-Pierce and Riedel 2000), possibly to take advantage of detritus when in shallow water.

Another potentially important food source in the summer are the macrophytes drifting into the Salton Sea from the surrounding tributaries. Even though tilapia

Table 1. Mean proportion (coefficient of variation; standard deviation/mean) of taxa identified from stomach contents. Mean proportions were calculated separately for phytoplankton, zooplankton, and benthos. Taxa are grouped by season and sampling area (R — river mouth; N — nearshore; P — pelagic). X — no fish sampled; numbers in parenthesis are quantity of stomachs analyzed (n).

	Spring			Summer			Fall			Winter		
	R	N	P	R	N	P	R	N	P	R	N	P
n =	(29)	(10)	(4)	(32)	(6)	(0)	(24)	(12)	(2)	(24)	(4)	(5)
Phytoplankton												
Diatoms	0.93 (3.16)	0.43 (1.17)	0.25 (2.00)	0.35 (1.36)	0.33 (1.55)	X	0.42 (1.21)	0.67 (0.74)	0	0.50 (1.02)	0.75 (0.67)	0.20 (2.24)
Dinoflagellates	0	0.07 (3.16)	0	0	0	X	0	0	0	0	0	0
Zooplankton												
Barnacles	0.39 (0.84)	0.06 (2.63)	0.09 (1.85)	0 (5.60)	0	X	0 (4.70)	0.02 (3.28)	0	0.50 (0.96)	0.98 (0.02)	0.24 (1.81)
Copepods	0.08 (2.40)	0	0 (2.00)	0.23 (0.93)	0.24 (0.94)	X	0.78 (0.41)	0.53 (0.57)	0.82 (0.32)	0.09 (3.00)	0.02 (1.16)	0.04 (2.24)
Rotifers	0.38 (0.84)	0.34 (1.35)	0.74 (0.67)	0.75 (0.33)	0.86 (0.14)	X	0.12 (1.80)	0.28 (0.84)	0.18 (1.41)	0.02 (4.90)	0	0.12 (2.24)
Amphipods	0	0	0	0	0	X	0	0	0	0.01 (4.90)	0	0
Cladocera	0.02 (2.79)	0 (3.16)	0 (2.00)	0	0	X	0.04 (4.90)	0	0	0	0	0
Insects	0.01 (3.78)	0 (3.16)	0.17 (1.98)	0	0	X	0 (3.70)	0	0	0.01 (4.90)	0	0
Benthos												
Nematodes	0.29 (1.43)	0.78 (0.28)	0.85 (0.07)	0 (4.65)	0.03 (2.45)	X	0.58 (0.83)	0.50 (1.01)	0.25 (1.41)	0.36 (1.26)	0.01 (1.70)	0.20 (2.24)
Ciliates	0	0	0	0.62 (0.79)	0.54 (0.84)	X	0	0	0	0.04 (4.90)	0.71 (0.67)	0
Pile Worms	0.31 (1.32)	0.22 (1.00)	0.13 (0.49)	0.06 (3.93)	0.26 (1.61)	X	0.15 (2.23)	0.41 (1.21)	0.75 (0.47)	0.22 (1.74)	0.03 (0.85)	0
Ostracods	0.02 (5.39)	0	0	0.03 (5.66)	0	X	0.02 (3.50)	0	0	0	0	0

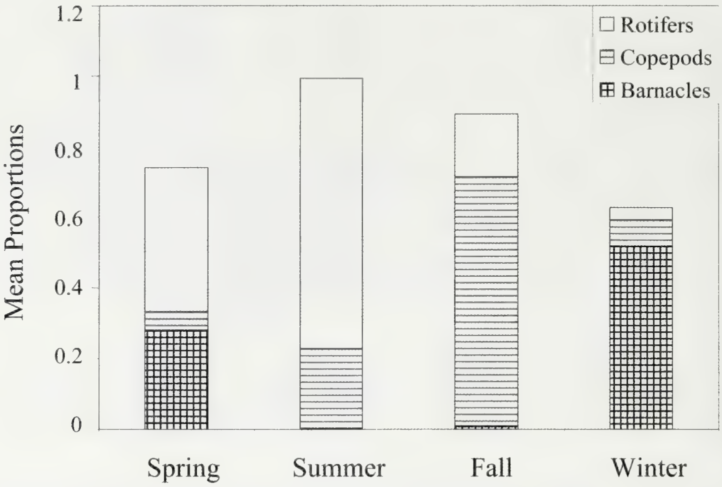

Fig. 4. Mean percentages over sampling areas of most frequent zooplankton in the diet of tilapia sampled at the Salton Sea. Differences in mean percentages by sampling area were not statistically significant. Spring n = 43, summer n = 38, fall n = 38, winter n = 33.

are not obligate herbivores, the high stomach acidity make tilapia an opportunistic herbivore. The digestibility of plant material in tilapia is not as high as that for true herbivores such as common carp (*Cyprinus carpio*), but high enough to provide some nutritional benefit (De Silva and Perera 1983). The highest concentration of tilapia in the summer is within the mixing zones between the river mouths and the Salton Sea proper (Riedel and Costa-Pierce 2002; Costa-Pierce and Riedel 2000). Fish seek the lower temperatures and higher dissolved oxygen at those locations. Tilapia may also prefer the river mouths because of the added benefit of macrophyte drift.

The importance of the phytoplankton to Salton Sea tilapia may have been underestimated because most phytoplankton cells may have been lost during our filtration or not captured during our plankton tows, due to the large mesh size we used. Our results, however, for the larger phytoplankton show that diatoms are the most important food item. The abundance of diatoms at the Salton Sea declines during the summer (Carpelan 1961a). Similarly, diatoms were less abundant in tilapia stomachs during that season. The proportions of barnacles, copepods, and rotifers in fish stomachs correlated well with their proportions in the water column and with the seasonal abundance patterns described in other studies (Carpelan 1961b; Tiffany et al. 2002). Tilapia species have been known to be unselective feeders (Beveridge *et al.* 1989). The close agreement between taxa in fish stomachs and taxa in the water column is evidence for low electivity for Salton Sea tilapia when feeding within the water column.

Pile worms become restricted to shallow areas of the Salton Sea in the summer due to anoxia and recolonize deeper areas in the fall and winter (Detwiler *et al.* 2002). Pile worms in tilapia stomachs increased during the recolonization period, indicating the importance of this food item for tilapia. Ciliates and nematodes were observed in tilapia stomachs and may contribute to the nutritional value of sediment, but are likely not as important as pile worms due to their small sizes.

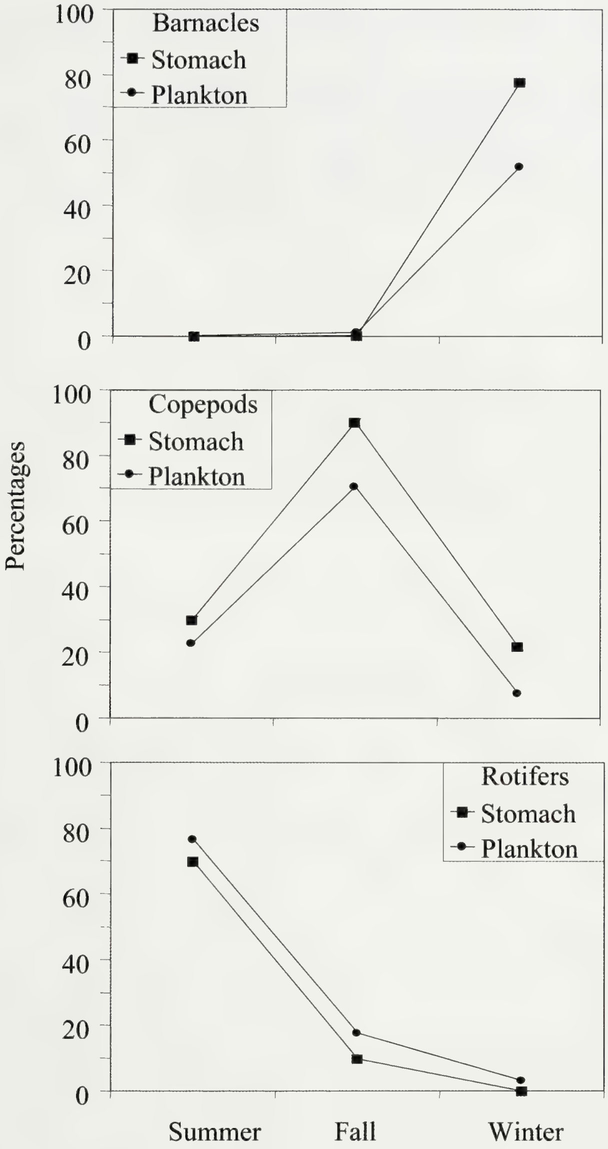

Fig. 5. Contrast between frequency of barnacles, copepods, and rotifers from tilapia stomachs and from the Salton Sea water column during the summer, fall and winter, 2000. Chi-square of summer = 0.04 (ns), fall and winter = 0.18 (ns); Observed—percentages in tilapia stomachs, Expected—percentages in the water column from plankton tows.

The higher occurrence of pile worms in tilapia stomachs from the river mouths may be due to the higher aeration of the sediment at that area.

We did not observe a pattern in the color of intestinal material possibly because tilapia do not feed exclusively on plants. Epiphytic algae and aquatic vegetation are low at the Salton Sea, except for macrophytes drifting from the incoming tributaries. Salton Sea tilapia, including specimens at the river mouths, rely mostly

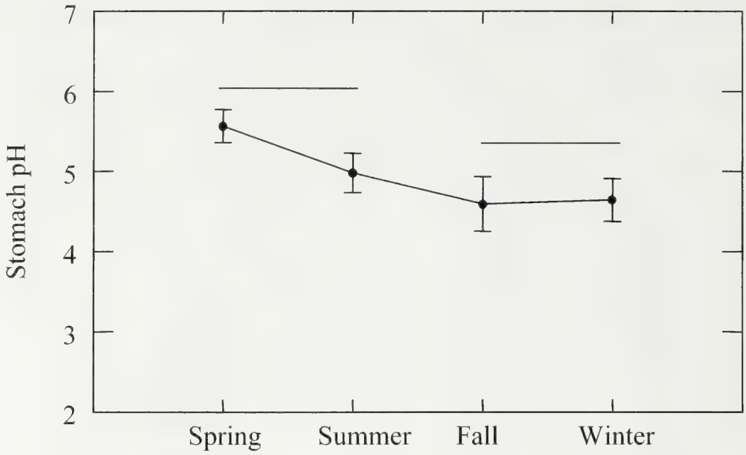

Fig. 6. Mean ± SEM stomach acidity by season for tilapia stomachs at the Salton Sea. Horizontal bars indicate analysis of variance post-hoc groupings (Fisher's LSD, $p < 0.05$; $p = 0.02$ for factor season, 104 df).

on plankton and benthic organisms for food, keeping the color of intestinal material brown, even if food is not digested.

Tilapia at the Salton Sea reproduce from the spring to the end of summer (Riedel *et al.* 2002). According to our stomach acidity data, tilapia feeding increases during fall and winter. In the spring, tilapia are getting ready to reproduce and in the summer tilapia are stressed from anoxia and high temperatures. The critical period for growth may be a short period between the fall and winter before temperatures decrease below suboptimal, and the early spring, before reproduction. During those periods, we observed many fish stomachs full with adult pile worms, further evidence of the importance of this polychaete in determining tilapia condition and supporting its population.

The Salton Sea recently experienced massive bird mortalities (Tetra Tech 2000). Among the culprits is a bacterium, *Clostridium botulinum,* which causes botulism in pelicans. Pelican mortality is highest during summer and is possibly mediated by tilapia. Pelicans feed on tilapia infected with the bacterium. Because the bacterium and its spore are inhibited from growing in acid environments (pH 4.6 or below), we hypothesize that *C. botulinum* should be more common in tilapia stomachs during the spring and summer, based on the patterns of tilapia stomach acidity found here (Figure 6).

The success of Salton Sea tilapia may be attributed to its high feeding plasticity. Fish derive nutritional value from plants and plankton in the summer, but rely mostly on the pile worms during the fall and winter, making those seasons critical for tilapia growth and production. Because of the predominance of pile worms in the sediments during the fall and winter (Detwiler *et al.* 2002), they are likely responsible for the high growth rates and production of Salton Sea tilapia.

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Microhabitat Segregation of Three Species of Pocket Mice (Genus *Chaetodipus*) in Coastal Baja California, Mexico

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Abstract.—I compared vegetation and substrate characteristics at capture locations of three syntopic species of pocket mice (*Chaetodipus*: Heteromyidae) to determine differences in microhabitat affinities of these ecologically similar rodents in coastal Baja California, México. Principal components analysis revealed that capture locations of *C. spinatus* had disproportionately higher cover of medium and large rocks, and tended to have higher plant species diversity than capture locations of the other two species. *C. spinatus* and *C. arenarius,* the two smallest species, differed most in their microhabitat affinities, suggesting spatial segregation that may minimize competition for similar food resources. *C. arenarius* was captured most often at sites with the finest-textured soils, whereas *C. rudinoris,* the largest species, was widespread and frequently associated with gravel and small rocks. No species showed any apparent preference for plant species or significant amounts of overhead cover, a conclusion supported by the high densities of *C. rudinoris* on small, barren islands in the Gulf nearby. My results represent the first quantitative descriptions of the habitat associations of these species, which are wholly or predominantly restricted in their distributions to Baja California.

Studies of desert rodents have provided important insights into the mechanisms that permit species coexistence (Kotler and Brown 1988; Brown and Harney 1993). Desert rodent communities are often incredibly diverse, containing as many as 14 species, and in the case of North American deserts, are dominated by granivorous heteromyids (Brown and Harney 1993). The co-occurrence of multiple, ecologically similar heteromyid species has been attributed to subtle differences in diet (e.g., Brown and Leiberman 1973; M'Closkey 1978), foraging efficiency (Price and Heinz 1984; Price and Waser 1985; Brown 1989), predator escape abilities (Kotler 1984; Longland and Price 1991) and body size (Bowers and Brown 1982), all of which reflect the long-term consequences of competition, predation risk and biogeographical history (Brown and Harney 1993). These differences usually are manifest in patterns of microhabitat use (e.g., Price 1978; Wondolleck 1978; Thompson 1982), with species separated locally in space by the amount and species composition of plant cover and soil and substrate characteristics (Reichman and Price 1993).

As part of a study of the ecology of coastal and insular populations of rodents in northern Baja California, I captured three species of pocket mice (*Chaetodipus arenarius, C. rudinoris* and *C. spinatus*) in very close proximity to one another, at locations with seemingly similar vegetation and substrate features. I recorded microhabitat characteristics at capture locations of each species to look for evidence of microhabitat partitioning that might explain the co-occurrence of these otherwise ecologically similar species, which comprise approximately 75% of captures of rodents in the study area (Stapp and Polis 2003). These species have their distributions either wholly (*C. arenarius*) or predominantly (*C. spinatus, C. rudinoris*) in Baja California (Lackey 1991*a, b*; Paulson 1988), yet little is known of their ecology outside of the general habitat descriptions provided in taxonomic references (e.g., Burt 1932; Huey 1964). Riddle et al. (2000) recently proposed that populations of *C. baileyi* west of the Colorado River are a distinct species, *C. rudinoris.* To my knowledge, this study provides the first quantitative descriptions of the habitat affinities of these species.

Methods

The study was conducted from May–October 1998 in a wide desert bajada located 10 km north of Bahía de los Angeles, along the Gulf coast of Baja California, México. Vegetation is Sonoran desert scrub and dominated by perennial shrubs (*Bursera hindsiana, B. microphylla, Fouquieria* spp., *Lycium* spp., *Larrea tridentata, Jatropha cuneata*), short trees (*Olneya tesota, Pachycormus discolor, Cercidium microphyllum*) and cardons (*Pachycereus pringlei*). *Frankenia palmeri, Suaeda moquinii* and *Salicornia subterminalis* are the dominant plants in a narrow zone of fine-textured soil 50–75 m from the shore. The beaches adjacent to the study area were covered with smooth cobble. Annual plants were abundant inland in the spring of 1998, following a strong 1997–98 El Niño Southern Oscillation event that brought 440 mm of rain to the area, which normally receives <59 mm annually (Stapp and Polis 2003).

In May 1998, I established two 1.5-ha trapping grids, separated by approximately 1 km. Grids consisted of 54 trap stations, with six parallel transects originating in the supralittoral zone and extending inland perpendicular to the shore for 200 m. Transects were 15 m apart and consisted of nine stations spaced at 25-m intervals. Each trap station had a single Sherman live trap, which was baited with peanut butter and oats. The size of the grid was reduced to four transects in October 1998 (36 traps; 0.9 ha).

Rodents were live-trapped for three consecutive nights in May and October 1998, but because feral dogs disturbed many traps on the third night, I used only data from two nights of trapping in each session to estimate species composition and relative abundance. Traps were opened at dusk and checked and closed at dawn each morning to prevent heat-induced mortality. Each individual captured was measured, weighed and given a uniquely numbered aluminum ear tag. All individuals were released at their capture location. I used the number of individuals captured per unit trapping effort as an index of relative abundance.

Vegetation and substrate characteristics were recorded within a 3-m radius plot of each trap station where different *Chaetodipus* were captured, omitting recaptures of the same individual at the same station. I recorded the number of species of trees (≥2 m in height), shrubs, and ground cover plants (mostly annuals), and estimated visually the percentage canopy cover of plants in the plot. I characterized the percentage cover of each type of substrate within each plot, using the following categories: sand; marine silt; small rocks (ca. 2–10 cm diameter); medium rocks (10–30 cm); large rocks (>30 cm). Another observer and I estimated percentage cover of plants and substrate independently, and the mean of these

Table 1. Relative abundance [number of individuals/100 trap-nights (TN)] of rodents on two, 1.5-ha coastal study areas near Bahía de los Angeles, Baja California, México in 1998. The number of unique trap stations used denotes the number of different trap stations where each species was captured. Mean abundance was calculated for May and October trap sessions on each site; values presented are the means ± 1 s.e. of the two study areas. For comparison, 44% of all trap stations were ≤75 m from shore. Body weights are means ± 1 s.e., with n in parentheses, based on live-trapping on the mainland between 1997–2001 (P. Stapp, *unpubl. data*).

Species	Adult body weight (g)	No. individuals (total captures)	Relative abundance (No./100TN)	No. of unique trap stations used	Percent of capture locations ≤75 m from shore
Chaetodipus rudinoris	19.5 ± 0.4 (59)	49 (59)	14.34 ± 4.69	42	40.48
Chaetodipus spinatus	15.0 ± 0.3 (50)	42 (43)	14.69 ± 1.25	34	17.65
Chaetodipus arenarius	11.2 ± 0.1 (25)	16 (17)	5.23 ± 0.01	16	50.00
Dipodomys merriami	34.2 ± 1.0 (18)	16 (19)	5.57 ± 3.11	14	57.14
Peromyscus eremicus	16.2 ± 0.5 (17)	7 (8)	2.72 ± 0.30	8	37.50
Neotoma lepida	131.8 ± 7.5 (10)	7 (9)	2.24 ± 0.26	7	85.71

estimates was used in data analysis. Principal components analysis was used to reduce the number of correlated variables for comparisons of differences in microhabitat associations of each species. Within each plot, I also recorded presence of mounds with extensive burrow systems to evaluate the efficacy of using these burrow networks as an indicator of species presence.

Results

Six rodent species were captured on both study sites (Table 1). As in other Sonoran Desert communities, heteromyids were numerically dominant. Sigmodontine rodents (*Peromyscus eremicus, Neotoma lepida*) were captured only occasionally and represented by few individuals. *Chaetodipus spinatus* and *C. rudinoris* were most abundant and captured in approximately equal numbers, whereas *C. arenarius* and *Dipodomys merriami* were less common. Although all species except *D. merriami* were captured in traps in the supralittoral zone, *C. spinatus* was largely restricted to scrub vegetation far from shore (Table 1). In contrast, *C. rudinoris* and *C. arenarius* were dispersed fairly uniformly across the trapping areas. *N. lepida,* an herbivorous species typically associated with rocky slopes and outcrops, was restricted primarily to the dense *Salicornia* and *Suaeda* cover near shore (Table 1). *C. formosus* is known to be present in the area (Stapp 2002; G. Stewart, *pers. comm.*), but was not caught on the study sites during my study.

Analysis of microhabitat variables at capture locations suggested differences among species in their affinities for local substrate and soil characteristics. Four principal components had eigenvalues >1.0, with the first principal component axis (PC1) accounting for nearly 28% of the variance (Table 2). The three species differed only in their scores for PC1 (Kruskal-Wallis test, $\chi^2 = 9.20$, d.f. = 2, $P = 0.01$; all other PC axes, $P > 0.19$). Capture stations of *C. spinatus* had significantly higher mean scores for PC1 (mean ± 1 s.e. = 0.65 ± 0.25) than those where *C. rudinoris* (−0.33 ± 0.21) and *C. arenarius* (−0.52 ± 0.31) were caught. Based on the correlations between microhabitat variables and PC1 (Table 2), capture locations of *C. spinatus* were significantly more rocky (i.e., had proportion-

Table 2. Microhabitat characteristics (mean ± 1 s.e.) of capture locations of three species of *Chaetodipus* near Bahía de los Angeles, Baja California, México. Sample size is the number of unique trap stations used by each species (Table 1). The major plant species listed were those present at ≥20% of capture locations of a given species. The last four columns are correlations between four principal components with eigenvalues >1.0 and variables describing vegetation and substrate characteristics.

				PC correlations			
Microhabitat variable	*C. rudinoris*	*C. spinatus*	*C. arenarius*	PC1	PC2	PC3	PC4
No. tree species	0.40 ± 0.11	0.50 ± 0.11	0.31 ± 0.12	0.42	0.26	−0.05	0.50
No. shrub species	1.88 ± 0.17	2.12 ± 0.23	1.88 ± 0.26	0.32	−0.22	0.50	−0.20
No. understory species	3.10 ± 0.36	3.91 ± 0.27	2.88 ± 0.50	0.21	0.49	−0.16	−0.36
% plant cover	27.07 ± 2.79	21.12 ± 3.08	30.94 ± 4.94	−0.19	−0.30	0.36	0.59
% sand or silt	68.81 ± 5.11	58.53 ± 5.42	78.75 ± 5.82	−0.54	0.40	0.16	0.06
% small rock	23.33 ± 4.64	15.88 ± 4.59	11.56 ± 4.13	0.15	−0.60	−0.41	−0.17
% medium rock	3.69 ± 8.77	22.35 ± 4.85	5.94 ± 2.75	0.47	0.12	0.49	−0.09
% large rock	4.17 ± 2.09	3.09 ± 1.12	2.19 ± 1.51	0.32	0.15	−0.40	0.44
Major tree species[a]	PADI, FOSP, BUHI	PADI, FOSP, BUHI, OLTE	PADI, FOSP, BUMI, CEMI, PAPR				
Major shrub species[b]	FRPA, LYCI, LATR, SUMO, SASU	LYCI, LATR, JACU, VIGE	FRPA, LYCI, LATR, BUMI, JACU				
Major understory species[c]	PEEM, ARAD, EUPH, DAES, MAEV	PEEM, ARAD, EUPH, DASE, MAEV	PEEM, ARAD, EUPH, MAEV				
Eigenvalue				2.21	1.79	1.32	1.12
% variance explained				27.63	22.36	16.51	14.06

[a] PADI, *Pachycormus discolor*; FOSP, *Fouquieria* spp.; BUMI, *Bursera hindsiana*; BUMI, *Bursera microphylla*; OLTE, *Olneya tesota*; CEMI, *Cercidium microphyllum*; PAPR, *Pachycereus pringlei.*

[b] FRPA, *Frankenia palmeri*; LYCI, *Lycium* spp.; LATR, *Larrea tridentata*; SUMO, *Suaeda moquinii*; SASU, *Salicornia subterminalis*; JACU, *Jatropha cuneata*; VIGE, *Viscainoa geniculata.*

[c] PEEM, *Perityle emoryi*; ARAD, *Aristida adscensionis*; EUPH, *Euphorbia* spp.; DASE, *Dalea seemannii*; MAEV, *Marina evanescens.*

ately less fine-textured soil) and tended to have overall higher plant species diversity than those of the other two species. This interpretation is supported by inspection of the mean values of the microhabitat variables separately (Table 2). However, capture locations of the three species tended to be dominated by the same plant species. The presence of *Frankenia, Suaeda* and *Salicornia* at capture locations of *C. rudinoris* and, to a lesser extent, *C. arenarius,* reflected the frequent captures of these species in coastal vegetation.

The degree of overlap among captures of the three *Chaetodipus* species provides additional evidence of differential microhabitat use by the two smallest (and presumably, most similar ecologically) species. *C. rudinoris* and *C. spinatus* were often captured at the same trap (36% and 44% of *C. rudinoris* and *C. spinatus* captures overlapped, respectively), but *C. spinatus* rarely overlapped with the smaller *C. arenarius* (12% and 25% of *C. spinatus* and *C. arenarius* captures, respectively). In inland areas where *C. spinatus* was most abundant, *C. arenarius* was restricted to the sandy bottoms of dry washes.

Mounds with extensive burrow networks were present at 26–35% of capture locations of *Chaetodipus,* which implies that the presence of mounds is not a reliable indicator of trap success. Capture locations with these mounds were always associated with *C. spinatus* or *C. rudinoris,* and mounds were present at several locations where only one of these species was captured, suggesting that both build mounds. In contrast, all *C. arenarius* capture locations with mounds were trap stations where other species were also captured, suggesting that *C. arenarius* does not construct these mounds.

Discussion

Three species of pocket mice were captured in close proximity to one another, and often, at the same locations, in two trapping areas in coastal Baja California. There were no obvious differences among species in plant cover or species composition at capture locations, although areas inhabited by *C. spinatus* tended to have higher overall plant diversity than capture locations of the other two species. All species were captured frequently in locations with little overhead cover (>50% of capture locations had <20% plant cover). The two smallest species differed primarily in their preference for different substrates, with *C. arenarius* being restricted to the finest-textured soils, and *C. spinatus* associated with a mixture of substrates that included more medium and large rocks. *C. rudinoris,* the largest pocket mouse locally (Table 1), was also the most widespread, and was clearly more generalized in its microhabitat affinities. Both *C. rudinoris* and *C. arenarius* were captured frequently in coastal vegetation, the latter in sand and fine marine silt, and the former in areas with gravel and small stones. The ability of *C. rudinoris* to use gravelly substrates has been reported previously for the closely related *C. baileyi* (Rosenzweig and Winakur 1969; Price 1978; Wondolleck 1978), and may explain the persistence of *C. rudinoris* on small (<0.2 km^2 area) islands just offshore (Lawlor et al. 2002). Although islands in Bahía de los Angeles are extremely rocky and sparsely vegetated, *C. rudinoris* maintains high population densities on these islands (Stapp and Polis 2003).

Interspecific differences in substrate affinities may reflect differences in relative foraging efficiencies of the three species, as well as variation in the number and size distribution of seeds among microhabitats (Reichman 1984). Unfortunately, these data are lacking for my study area and the three species I studied. Laboratory experiments (Price and Heinz 1984) suggested that heteromyids, regardless of size and morphology, forage most efficiently when seed densities are high and soils are sandy. However, *C. baileyi,* the close congener of *C. rudinoris,* and *Perognathus amplus,* which is similar in size and morphology to *C. arenarius* (Table 1; Price and Heinz 1984), differed in their preferences for soil texture, with *C. baileyi* preferring coarse soils and *P. amplus* extracting more seeds from fine-textured soils (Price and Waser 1985). In my study, *C. arenarius* and *C. rudinoris* seemed to overlap in their microhabitat associations, but they may select soil characteristics on a finer scale than could be detected by my sampling methods. However, given the large difference in body size (9 g; Table 1) between these two species, they may also have distinct preferences for different sizes or spatial distribution of seeds that may explain their co-occurrence. More information on the density and accessibility of seeds in rocky substrates, on the foraging behavior of *C. spinatus,* and on possible competitive effects of *C. rudinoris* on the smaller pocket mice is needed to assess patterns of spatial overlap in this system.

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McWilliams, K. L. 1970. Insect mimicry. Academic Press, vii + 326 pp.

Holmes, T. Jr., and S. Speak. 1971. Reproductive biology of *Myotis lucifugus.* J. Mamm., 54:452–458.

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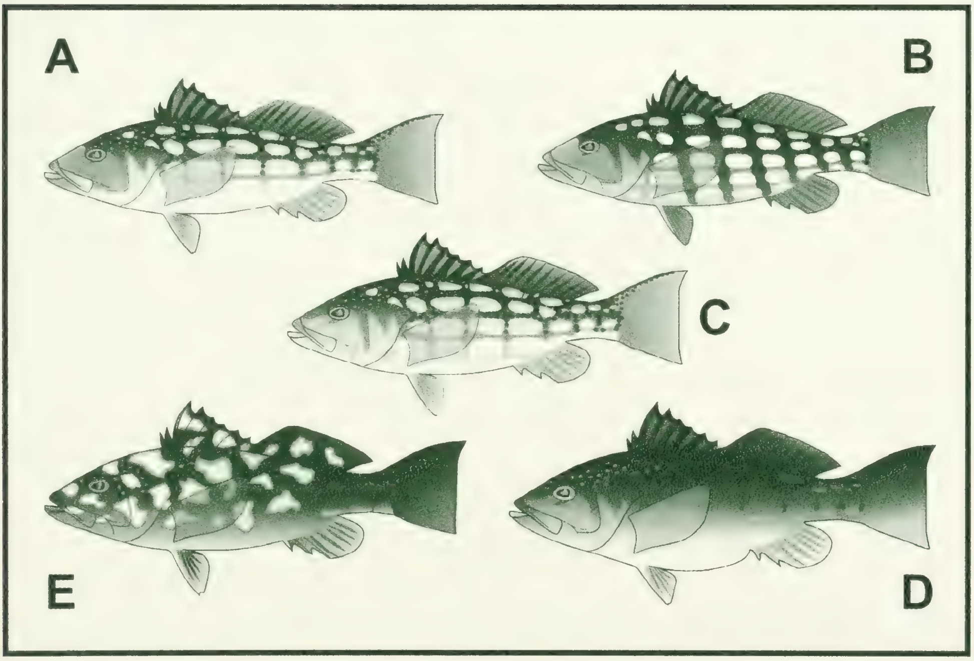

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Color Patterns and Associated Behaviors in the Kelp Bass, *Paralabrax clathratus* (Teleostei: Serranidae)

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Abstract.—Seasonal and ephemeral color patterns in the kelp bass, *Paralabrax clathratus,* were studied on Santa Catalina Island, California from April 2000 to September 2002. Adults were monochromatic for part of the year (calico phase) and sexually dichromatic from April to October, with most adult males adopting bright orange snouts (OS phase). The seasonal occurrence of the OS phase in males overlapped with the spawning season, and the color was limited to ripe males. The OS phase in ripe males may function as a signal of sexual identity and sexual readiness to females. Both males and females exhibited distinct color patterns during courtship and spawning periods. During these periods, males were charcoal colored with dark black bars overlaying white spots (checkered phase), and females were often black with no visible spots (dark phase). Color patterns displayed by adults during spawning activities may facilitate mate signaling and the formation of spawning groups. Specific color patterns were also observed in relation to habitat and aggressive behaviors.

Fishes are unique among vertebrates in their ability to display a wide variety of permanent and temporary color patterns, which are believed to be important in both social and environmental interactions (Townsend 1929; Cott 1940; Lorenz 1962). Some species exhibit permanent sexual dichromatism, where different color patterns are adopted for each sex and retained for life (DeMartini 1985; Kodric-Brown 1998). Conversely, monochromatic fishes often exhibit patterns of seasonal sexual dichromatism during the spawning season, and these color patterns are only adopted by actively breeding individuals (Thresher 1984; Kodric-Brown 1998). Ephemeral color changes, which usually persist for only brief periods of seconds to minutes, are widespread among fishes and occur under a variety of conditions including courtship, agonistic interactions, feeding, and changes in habitat (Losey 1976; Thresher and Moyer 1983).

Color patterns have often been used as key characters for identifying species within the family Serranidae (Heemstra and Randall 1993). Permanent dichromatism has not been described in the Epinephelinae but is common in the Anthiinae in association with sex change and sexual dimorphism (Shapiro 1981). Among serranines, permanent dichromatism has been reported in at least two species, black sea bass, *Centropristes striatus,* and barred serrano, *Serranus psittacinus* (Lavenda 1949; Hastings and Petersen 1986). Seasonal and ephemeral color changes in serranids are well known and are most commonly associated with the social behavior (i.e. courtship, aggression) of groupers (Colin 1992; Gilmore and Jones 1992; Sadovy et al. 1994), and color change has also been related to habitat (Townsend 1929; Smith 1971; Nemtzov et al. 1993). Investigations of color changes and associated behavior in serranines have focused mainly on two genera, *Serranus* and *Hypoplectrus,* both of which have tropical distributions (Clark 1959; Thresher 1984; Hastings and Petersen 1986).

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Color patterns and associated behaviors of temperate serranines are poorly understood, although brief descriptions of sexual dichromatism have been reported in the genus *Paralabrax.* Male *P. maculatofasciatus* (spotted sand bass) adopt a pale body color with white chins during the spawning season, where as females become darker in coloration with yellow chins (Allen et al. 1995). During spawning, male *P. maculatofasciatus* often adopt a high-contrast body coloration consisting of dark vertical bars overlaying a white body background (Miller 2004). In *P. nebulifer* (barred sand bass), breeding males are a high-contrast gray and white color, and they develop golden-yellow crescents below their eyes that are not well developed in females (Allen and Hovey 2001). Other members of the genus exhibit permanent sexual dichromatism. Adult male *P. loro* (parrot sand bass) have bright orange dorsal fins and cheeks, and the females have red dorsal fins and cheeks (Thomson et al. 2000).

The functional significance of color change has not been examined in most serranids, including members of the genus *Paralabrax,* although color changes are believed to serve a similar purpose in all. Temporary color changes, whether seasonal or ephemeral, are usually associated with specific behaviors, where they function as social signals of motivation (Losey 1976; Thresher 1984; DeMartini 1985). Moreover, distinct color patterns, when coupled with courtship behavior, may enhance the conspicuousness of the color, thereby serving to attract the attention of potential mates (Thresher 1984; Kodric-Brown 1998). The combination of certain color patterns and display behaviors by adults may also convey information on their sexual identity and physiological state (Thresher and Moyer 1983).

The kelp bass, *Paralabrax clathratus,* is a temperate serranine fish that inhabits the nearshore, rocky-reef environments of southern California and northern coast of Baja California (Quast 1968; Miller and Lea 1972). Historically, the species has been an important component of local fisheries, which has led to a number of studies on various aspects of its biology (e.g. Quast 1968; Smith and Young 1966; Love et al. 1996). Histological evidence and sex-specific size frequency distributions of *P. clathratus* indicate a gonochoric sexual pattern, and no evidence of sex change has been reported (Smith and Young 1966; Oda et al. 1993). Recent studies by Erisman (2003) indicate that spawning occurs in single female, multi-male groups of 3 to 20 individuals within large breeding aggregations that form from late spring to early fall. Several hundred adults may aggregate in a small area during spawning. Spawning begins at sunset and occurs for several hours past dark. Unlike many tropical serranids, spawning in *P. clathratus* occurs continuously throughout the summer months and does not follow a lunar or semilunar rhythm (Erisman 2003).

The first scientific documentation of color changes in P. *clathratus* appeared in Quast (1968), who noticed that some males became "golden on the snout" during the breeding season. This color pattern was most frequently observed in small males, although the color was present in some larger males. Similar results were reported by Turner et al. (1969). These early observations suggested that *P. clathratus* were seasonally dichromatic, although the descriptions were vague and no systematic investigations of the color patterns or their relation to the spawning season were ever conducted.

The purpose of the current investigation was three-fold: 1) to document and describe seasonal and ephemeral color patterns in *P. clathratus,* 2) to record and describe behaviors associated with specific color patterns, and 3) to compare the color patterns of collected individuals by sex and reproductive condition. This study represents the first complete description of color changes and related behaviors in a temperate serranine fish.

Materials and Methods

Hook and Line Sampling

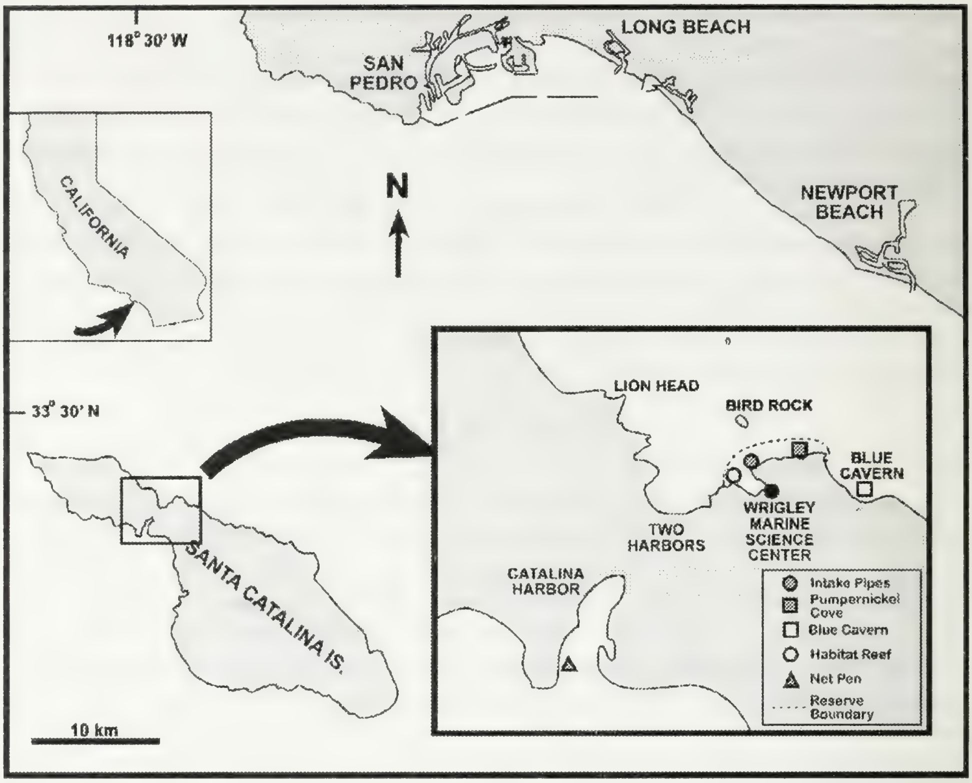
Eight hundred twenty-five individuals (365 males, 397 females, 63 juveniles) were collected by hook and line from May 2001 to April 2002 at several sites along the coast of Santa Catalina Island, California (33° 26′ N, 118° 29′ W) (Figure 1). In addition, 60 individuals were collected by hook and line in San Pedro, California on February 2002 (Figure 1). Collections were made on a monthly basis during the non-spawning season and daily during the spawning season. Standard length (SL) of each individual was recorded to the nearest mm and body weight was recorded to the nearest g. Time and date of collection and the lunar phase were recorded.

Macroscopic inspections of gonads were used to determine sex and maturity states of individuals (Hunter and Macewicz 1985; DeMartini 1987; Allen et al. 1995). When the determination of sex was uncertain, gonads were examined under a dissecting microscope for verification (Allen et al. 1995). Gonads were removed from all captured individuals and wet weights were recorded to the nearest 0.5 g.

The gonosomatic index (GSI) of adults and visual determinations of gonad maturity states were used to estimate the annual spawning season (Quast 1968; Sadovy et al. 1994; Rhodes and Sadovy 2002). GSI values for individuals were calculated by the following: GSI = (gonad weight/gonad-free body weight) × 100. Monthly variations in male and female GSI were analyzed using a Kruskal-Wallis test (nonparametric ANOVA), as these data did not conform to the assumptions of parametric analyses.

Swollen ovaries containing eggs enlarged with water and having clear yolks were classified as hydrated. Hydration was verified by comparing the mean GSI of hydrated ovaries with non-hydrated, ripe ovaries using an unpaired t-test. This data set conformed to the assumptions for performing parametric analyses. Hydrated ovaries were expected to have higher GSI values than non-hydrated, ripe ovaries (Hunter et al. 1985; Hunter and Macewicz 1985). Since spawning occurs in *Paralabrax* within 24 hours of hydration (Oda et al. 1993), dates on which hydrated females were collected were used as daily markers of spawning (Hunter and Macewicz 1985). These data were organized chronologically and combined with GSI data to estimate the duration of the spawning season in 2001.

All collected individuals were identified with respect to both body coloration and head coloration. Individuals were categorized for head coloration according


118° 30' W
SAN PEDRO
LONG BEACH
NEWPORT BEACH
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N
33° 30' N
SANTA CATALINA IS.
10 km
LION HEAD
BIRD ROCK
BLUE CAVERN
WRIGLEY MARINE SCIENCE CENTER
TWO HARBORS
CATALINA HARBOR
Intake Pipes
Pumpernickel Cove
Blue Cavern
Habitat Reef
Net Pen
Reserve Boundary

Fig. 1. A Map of Santa Catalina Island, California, showing study sites and proximity to the southern California mainland. Behavioral observations were conducted at several sites inside (Habitat Reef, Intake Pipes, Pumpernickel Cove) and outside (Bird Rock, Blue Caverns) the no-take marine reserve adjacent to the USC Wrigley Marine Science Center. Visual transects were conducted at the Intake Pipes site and the Pumpernickel Cove site. The captive study was conducted at the net-pen site, located on the southwest region of Catalina Harbor.

to the presence or absence of a golden to orange coloration on the snout. Individuals with any visible evidence of the coloration were defined as orange-snout (OS) phase (Figure 2a). Individuals showing no visible evidence of a golden to orange coloration were defined as calico phase (Figure 2c). No distinctions were made among OS phase individuals with respect to intensity or coverage of the coloration. Once it was determined that body coloration did not differ among collected males and females, later specimens were only identified with respect to snout coloration. The OS phase was compared by gender, month of observation, ripeness state, time period, and lunar phase. Absolute frequencies were compared statistically using Pearson chi-square goodness-of-fit tests. The GSI and standard length of collected ripe males were compared by color phase using a Mann-Whitney test, because data did not conform to the assumptions of parametric analyses.

Visual Transects

Monthly visual SCUBA transects were conducted at two sites, Intake Pipes and Pumpernickel Cove, at Santa Catalina Island (Figure 1) while on SCUBA from

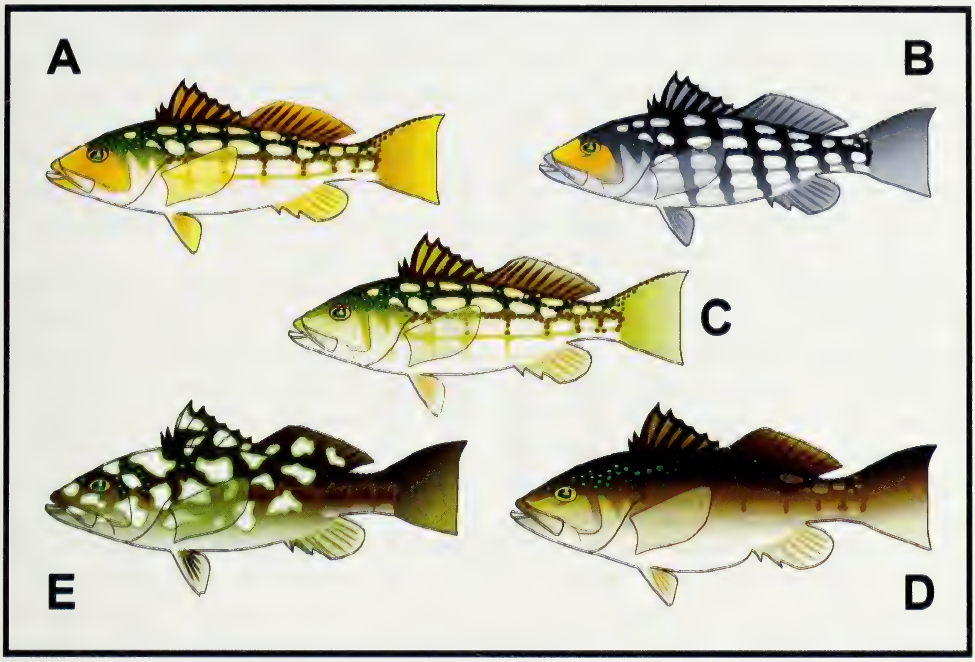

Fig. 2. Common color patterns in the Kelp Bass (*Paralabrax clathratus*). A = OS phase, B = checkered phase, C = calico phase, D = dark phase, E = marbled phase.

December 2001 through July 2002. Fixed transects 100 m in length were established at both sites at 9 m and 18 m depth. Dive surveys consisted of two divers swimming approximately 2 m above the bottom and 3 m apart from one another, counting all adults within 3 m while swimming along the transect. All individuals with estimated lengths of 220 mm TL or greater were identified as adults (Love et al. 1996). Adults were classified based on the presence/absence of orange snout coloration. Individuals with visible evidence of an orange snout coloration where identified as OS phase. Individuals showing no visible evidence of the OS color phase were identified as calico phase. When snout color could not be accurately determined, those individuals were not included. No depth effect was detected, so data were pooled for depth at both sites. None of the collected or observed immature individuals (< 220 mm TL) exhibited the snout coloration and these were excluded from further analyses.

Transects were only conducted when visibility levels exceeded 7 m to avoid possible errors related to poor visibility. Transects were conducted on consecutive days for each site. The frequency of individuals with orange snouts was defined as an average of individual frequencies observed per transect by the two divers. All dives were made between 1100–1400 hours to ensure maximal light levels and to eliminate variation in color patterns due to time of day. Variations in the proportion of OS males observed on transects at both sites were compared by month using a Pearson chi-square goodness of fit test.

Behavioral Observations

Behavioral patterns were documented based on approximately 450 hours of SCUBA or snorkeling observations from April 2000 to September 2002. Visual observations were recorded on plastic slates, and digital video recordings of behavior were analyzed for more detailed descriptions of behaviors. Behaviors including courtship, aggression, and spawning were initially identified based on their similarity to those described in other serranids (e.g. Thresher 1984; Sadovy et al. 1994; Deloach 1999). The coloration of individuals was used often to differentiate among males and females and to correlate color patterns with specific behaviors. Courtship and spawning behaviors are summarized in Erisman (2003) and will only be discussed in relationship to color change.

Behavioral observations were conducted at several locations on Santa Catalina Island, California. *In situ* observations were made at four sites within a no-take marine reserve (Habitat Reef, Intake Pipes, Pumpernickel Cove, Blue Caverns) located in the waters adjacent to the USC Wrigley Marine Science Center, and at one site (Bird Rock) located outside the reserve boundary (Figure 1). To collect more precise data on specific behaviors and associated color patterns, 108 (50 males, 58 females) adults were captured from 20 to 23 June 2002 and placed in a 700 m^3 outdoor, floating net-pen located in Catalina Harbor, Santa Catalina Island, California (Figure 1). The aggregation size and sex ratio used for the captive study was based on aggregation sizes described in previous studies (e.g. Quast 1968), and from numerous observations of aggregations conducted on SCUBA from 2000 to 2002. Captive individuals in the net pen were observed on a daily basis from 7 July to 14 August 2003, while on SCUBA or snorkeling, to document behaviors and color patterns.

Results

Seasonal Color Patterns

Kelp bass were sexually monochromatic for much of the year. Adults and immature individuals collected and observed during the fall, winter, and spring months were generally olive green to khaki brown on their side, dorsal, and head region. This color was integrated with pale spots present throughout the body, which gave them their characteristic "calico" appearance (Figure 2c, calico phase). Variations of the calico phase were present among collected individuals, and the body color pattern of collected individuals was similar to the colors of their surroundings. Individuals inhabiting areas with dense kelp appeared much more bronze or brown, with the spots less defined and a golden chin and belly, whereas individuals inhabiting more open water habitats were dull gray or light green, with white undersides.

Adult *Paralabrax clathratus* exhibited a pattern of seasonal sexual dichromatism, where most males collected and observed from May to early October had a conspicuous orange color on the snout region of their heads (Figure 2a, OS phase). However, some males did not show visible evidence of this color pattern and retained the calico phase during this period. The OS phase was not present in any females or immature individuals, and they exhibited the calico phase throughout the year. OS males were collected from May to October, and 75% of males collected from June to August showed this coloration (Figure 3). Monthly variations in the frequency of collected OS phase males were significantly different than expected at random (Pearson chi-square goodness of fit, χ^2 = 140.18,

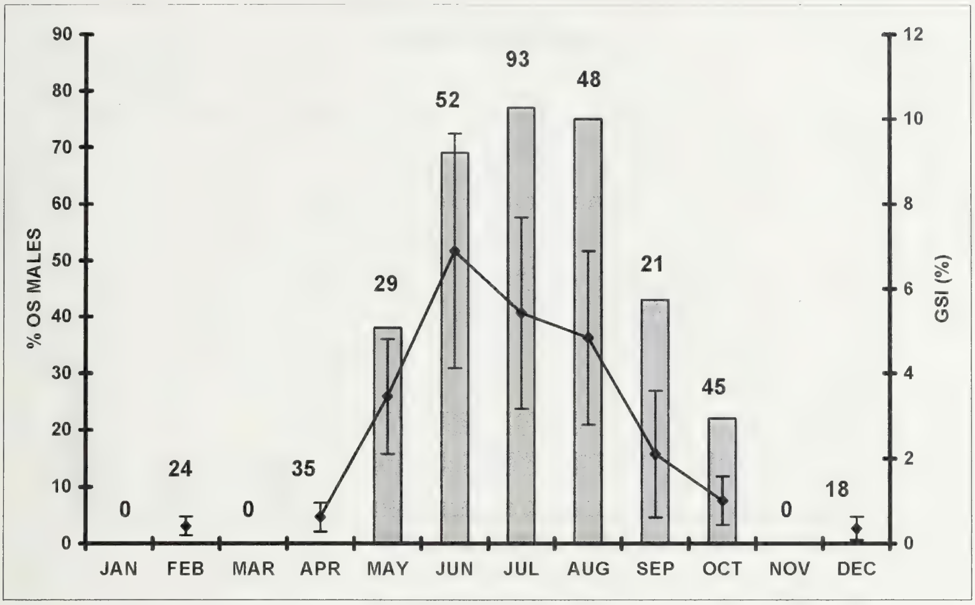

Fig. 3. Percent of OS males (bar graph) and gonosomatic index (GSI, line graph) from 365 male kelp bass (*Paralabrax clathratus*) collected from May 2001 to April 2002, by month of capture. Values for GSI are ± 1 SD. Numbers represent monthly sample sizes. Data were grouped to show monthly variations over a single year.

df = 8, $P < 0.01$). This coloration was not observed in any individuals collected from December 2001 to April 2002.

Calico phase individuals were observed at both transect sites throughout the study period (Figure 4). OS phase males were observed at both transect sites from May to July 2002, where they increased in frequency over this period (Figure 4). Monthly variations in the proportion of OS phase individuals observed on transects were significantly different than expected at random for both the Intake Pipes site (Pearson chi-square goodness of fit, $\chi^2 = 137.36$, df = 7, $P < 0.01$) and the Pumpernickel Cove site (Pearson chi-square goodness of fit, $\chi^2 = 173.81$, df = 7, $P < 0.01$).

The estimated spawning season based on GSI and maturity data showed a pattern very similar to the monthly frequency of collected OS phase males. Mean monthly GSI of males (Figure 3) and females (Figure 5) remained low from January to April. GSI of both sexes increased from April to June, peaked in June, and steadily declined throughout the summer and fall. GSI values of males and females were lowest in February and December. Monthly variations in male GSI (Kruskal-Wallis, KW = 222.24, df = 8, $P < 0.01$) and female GSI (Kruskal-Wallis, KW = 214.24, df = 8, $P < 0.01$) were significant. Males and females containing visibly ripe gonadal tissue were collected from May to October, and over 93% of adults collected from June to August were visibly ripe. Females with hydrated ovaries were collected from June through September, and the highest frequency of hydrated females occurred in July (Figure 5). The mean GSI of females with hydrated ovaries (5.79%) was significantly higher than the mean

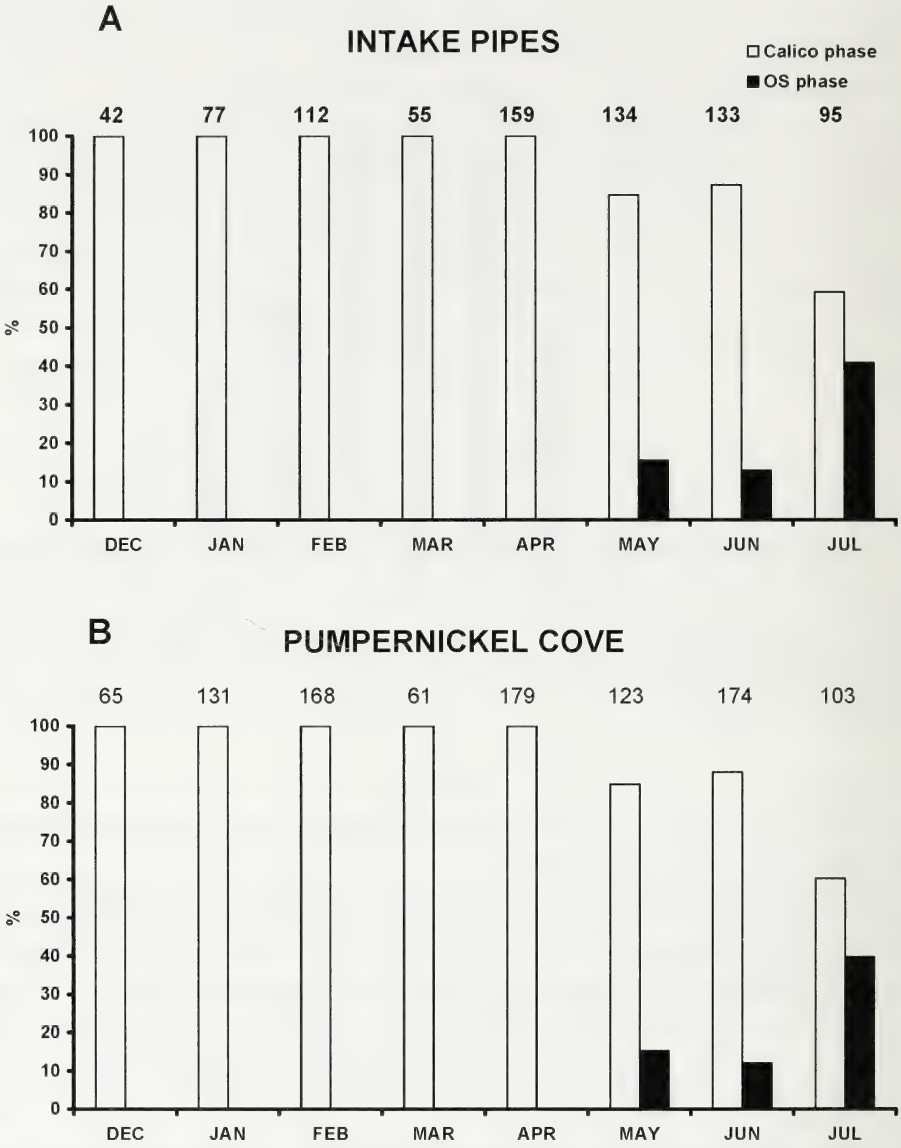

Fig. 4. Percent of calico phase and OS phase adult kelp bass (*Paralabrax clathratus*) from visual transects conducted at Santa Catalina Island, California from December 2001 to July 2002. A = Intake Pipes, B = Pumpernickel Cove. Numbers above bars represent monthly sample sizes.

GSI of non-hydrated, ripe females (3.56%; unpaired t test, $t = 7.78$, $df = 229$, $p < 0.01$).

OS phase individuals were present throughout the day and on a daily basis in both the field observations conducted from May to early October of 2000, 2001, and 2002, and in the captive study of 2002. OS phase individuals were not observed in field observations conducted in late October to April, from 2000 to 2002. Because no significant difference was found in the monthly frequency of the OS phase among males collected from June to August 2001 (Pearson chi-

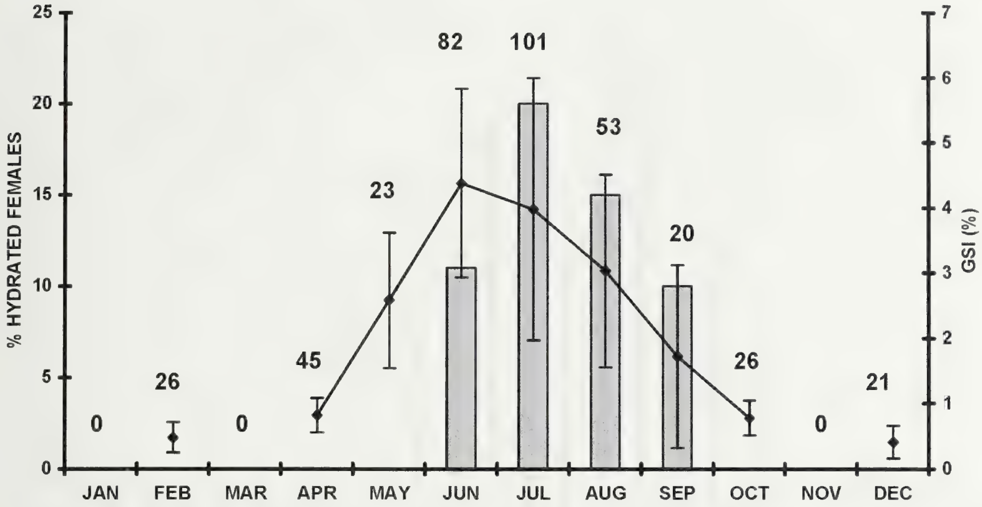

Fig. 5. Percent of females with hydrated ovaries (bar graph) and gonosomatic index (GSI, line graph) from 397 female kelp bass (*Paralabrax clathratus*) collected from May 2001 to April 2002, by month of capture. Values for GSI are ± 1 SD. Numbers represent monthly sample sizes. Data were grouped to show monthly variations over a single year.

square goodness of fit, $\chi^2 = 1.19$, df = 2, P = 0.55), data from all males collected from during this time were pooled for further analysis. During that period, OS phase males were collected throughout the day and showed no significant differences in frequency with respect to the time period captured (Pearson chi-square goodness of fit, $\chi^2 = 1.36$, df = 2, p = 0.51). Moreover, the frequency of OS phase males did not differ significantly among the four primary phases of the lunar cycle (Pearson chi-square, $\chi^2 = 4.45$, df = 3, P = 0.22).

OS phase males collected from May to October 2001 ranged in size from 165 to 386 mm SL, and calico phase males collected during that time period ranged in size from 170 to 397 mm SL (Figure 6). The mean length of collected OS phase males (263.01 mm) was significantly greater than the mean length of collected calico phase males (247.75 mm; Mann-Whitney, U = 5455.0, df = 247, P = 0.001). However, this result was not considered biologically significant, because adult *P. clathratus* grow to lengths of greater than 700 mm SL (Love et al. 1996). The size range of captive OS phase males (211 to 348 mm SL) was similar to that of captive calico phase males (212 to 343 mm SL). OS phase individuals observed in the field ranged in estimated size from 200 to 500 mm SL, while calico phase individuals observed ranged in size from 100 to 500 mm SL. The latter included individuals believed to sexually immature.

The OS phase was present only in ripe males, whereas the calico phase was present in both ripe and unripe males. Sixty-seven percent of ripe males collected during 2001 were OS phase and 33% were calico phase. Among males collected from May to October 2001, the GSI range of OS males (0.42% to 13.10%) were similar to that of calico phase males (0.17 to 12.94%) (Figure 7a). However, the mean GSI of OS males (5.69%) was significantly higher than that of calico phase males (2.88%) collected from May to October 2001 (Mann-Whitney, U = 3112.50, df = 237, P < 0.01) (Figure 7b).

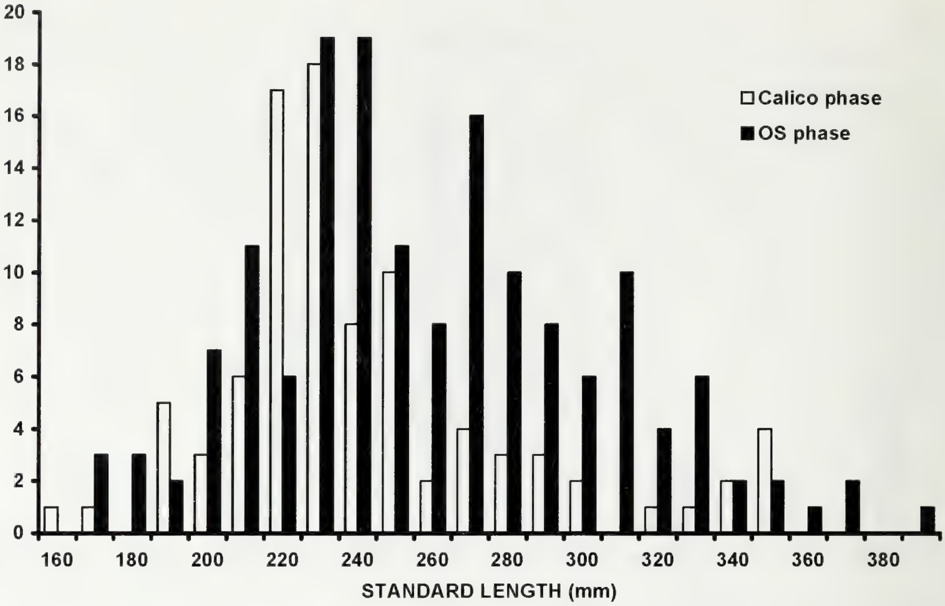

Fig. 6. Size-frequency distributions of 91 calico phase and 248 OS phase male kelp bass (*Paralabrax clathratus*) collected at Santa Catalina Island, California from May to October 2001.

During observations conducted in the field and in the captive study, OS phase males were observed engaging in courtship and spawning behavior with gravid females while aggregated in spawning groups. However, solitary OS males outside of aggregations were also common. Calico phase individuals were observed within spawning aggregations and exhibited courtship behaviors typical of spawning males. These calico phase individuals also participated in spawning events. However, it is not known whether these individuals were males or females in all cases. Low light levels and rapid movements of courting adults were common in field observations during the spawning period, which occurred at or beyond sunset at depths to 15 m. It was often difficult to identify the color patterns of all individuals participating in courtship behaviors and spawning rushes. The color patterns of individuals participating in courtship and spawning events were not identified for all spawning events observed in the field. Therefore, the relative proportion of OS males and calico phase males in spawning groups could not be accurately determined for field observations. Calico phase males were not observed participating in courtship and spawning events in the captive study.

Ephemeral Color Patterns

Instantaneous color changes and color patterns restricted to certain time periods or behaviors were documented in *P. clathratus* throughout the study. The calico phase was the most common body color pattern observed in the field. However, variations of the calico phase were observed when individuals moved from one habitat type to another, and individuals would often adopt body color patterns that matched their changing surroundings. For example, individuals moving from a kelp habitat to an open water environment changed color from a green or brown color variation of the calico phase to a pale green color variation. Similar changes

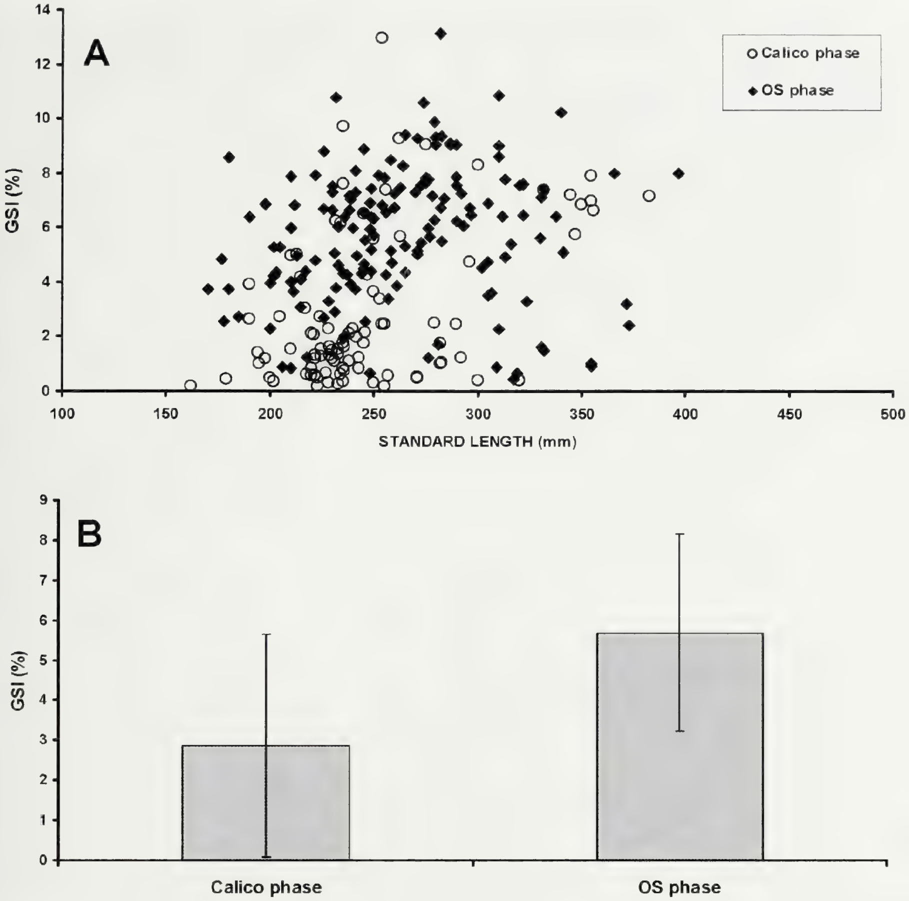

Fig. 7. Gonosomatic Index (GSI) of 91 calico phase and 248 OS phase male kelp bass (*Paralabrax clathratus*) collected at Santa Catalina Island, California from May to October 2001. A = scatter plot of GSI vs SL by color morph, B = comparison of mean GSI ± 1 SD by color morph.

in body color occurred when adults that were collected for the captive study were placed in clear aquaria. However, these individuals would switch colors again minutes after placement into the captive pens and match their surroundings. These instantaneous body color changes were observed for both males and females, including OS phase males.

During several observation periods, individuals involved in agonistic bouts changed colors instantaneously to a dark green or black body color with highly conspicuous white blotches covering the head and body (Figure 2e, marbled phase). The blotches were large, and they had a "'snowy" appearance that made the individual highly visible within its environment. This behavior was observed only 6 times in the field and was never observed in the captive study. Immediately following the end of the bout, individuals would re-adopt their former color pattern, which often matched their background. During brief aggressive interactions, often only one of the individuals would adopt this color pattern. The sex of marbled phase individuals is not known, although it was only observed for individuals greater than 200 mm SL and therefore may only occur in adults. The marbled phase was not adopted by courting males engaged in agonistic encounters with other males. Rather, courting males retained their courtship coloration, including the OS color pattern, during aggressive bouts. The marbled phase was not observed in any collected individuals.

Additional color patterns were observed during spawning periods, when males and females often adopted distinct courtship colors. During courtship and spawning events, OS phase males exhibited a charcoal gray color with large white spots covering the entire body. These individuals also possessed four to five black, vertical bars layered over the spots running the length of the body (Figure 2b, checkered phase). This color pattern was observed in the majority of captive males, was never observed outside of the spawning period, and was also observed in the field during spawning events. On a few occasions in the captive study, males observed during early courtship adopted this color pattern when posing or displaying to a female and then quickly changed back to a green color when courtship ceased. During the peak spawning time, however, all courting males exhibited this color pattern, although the checkered phase was not observed in any collected individuals.

During courtship and spawning, females were often dark to black with white bellies and indistinct spots (Figure 2d, dark phase). This dark phase color pattern was observed both in the field and in captive individuals, but was not documented in collected individuals. On many occasions, spawning groups were identified by a dark phase, gravid female swimming rapidly, followed by several checkered phase males with bright orange snouts. Although the dark color phase was observed in the field and in the captive study on many occasions, not all spawning females had this color pattern. In general, the dark color phase of the female appeared to be more common under lower light conditions. During one observation period in the captive study, a gravid female exhibited the dark phase for several minutes, changed body color to the calico phase for several minutes, and then reverted back to the dark phase just prior to spawning.

Discussion

Adult *Paralabrax clathratus* exhibited seasonal sexual dichromatism during the spawning season. GSI and maturity data indicate that adults began to ripen in April and May, and spawning occurred from June to September. The OS phase was present in males continuously from the late spring to early fall, regardless of time of day, day sampled, or lunar phase. OS phase males likely develop this coloration as they ripen and retain it throughout the spawning season until spawning activity ceases in the fall. The striking similarity between the seasonal occurrence of this color pattern and the spawning season, along with the fact that the OS phase was limited to ripe males, suggests that the orange snout coloration is an important component in the spawning behavior of adult kelp bass. The high GSI among OS phase males collected during the spawning season compared to the GSI of calico phase males collected during that period indicates that the OS color pattern may reflect the reproductive condition of males and may function as a signal of sexual readiness to mature females (Thresher 1984; Kodric-Brown 1998). Since males and females are monochromatic for most of the year, this color pattern may facilitate the identification of mates and the formation of spawning groups within the large aggregations which form during the spawning season (Thresher and Moyer 1983).

Although the majority of male kelp bass collected and observed during the spawning season were OS phase, this color pattern was not present in all males. Upon closer inspection of collected individuals, we found that the color would often fade in newly captured individuals placed in holding tanks, over the period of several minutes. From these observations, we concluded that the lack of this color in some collected males might have been due to excessive handling time before the color pattern was recorded. It is possible that stress may have induced color changes in collected individuals, although this was never tested. Potts (1974) noted that the color patterns of the corkwing wrasse, *Symphodus melops,* varied under different levels of stress, and individuals often adopted a "fright coloring" for several days before being replaced by a more neutral color pattern.

The small number of calico phase males collected and observed in the field during the spawning season could also be due to other factors. The OS color phase may be stimulated by a high density of aggregating adults. This would explain the high percentage of OS males in the captive study (92%) compared to that among collected males and individuals observed in the field. The captive study simulated a dense aggregation of breeding adults, whereas individuals collected and observed in the field were not always within aggregations. In the Nassau grouper, *Epinephelus striatus,* courtship color patterns and spawning activity are less intense in low-density populations than in large aggregations (Colin 1992).

Alternative mating phenotypes are common in many species characterized by sperm competition, where males must compete for mating access to females (Gross 1996; Parker 1998; Petersen and Warner 1998). "Bourgeois males" (Taborsky 1997) gain access to females through direct monopolization of females, attractive courtship behaviors, or secondary sexual characters (e.g. color patterns). In contrast, "parasitic males" (Taborsky 1997) gain access to females by exploiting the reproductive investment of bourgeois males through sneak spawning, female mimicry, and other forms of parasitic spawning (Gross 1982; Taborsky 1994; Uglem et al. 2001). Parasitic males experience higher intensity of sperm competition and have relatively larger gonads for their size than bourgeois males (Stockley et al. 1997; Taborsky 1998). Parasitic males also tend to be smaller than bourgeois males, because parasitic males invest considerable energy in sperm production rather than growth (Taborsky et al. 1997; Neat 2001).

Paralabrax clathratus may exhibit alternative mating tactics, with OS males making an investment in attractiveness, and calico phase males increasing their potential reproductive success by mimicking females. However, the existence of an alternative mating strategy by some male kelp bass is not supported by the observed behaviors of breeding males. Aggressive interactions among males were extremely rare, and males were not excluded from mating access with females. Courtship involved several males simultaneously chasing and mobbing a gravid female, and alternative courtship behaviors were not observed. Although the mating system of kelp bass was characterized by sperm competition, as shown by the high GSI among collected ripe males and group spawning behavior, the gonadal characteristics and size distributions among male color morphs were not consistent with that of a species with alternative mating tactics. The GSI of calico phase males were lower than OS phase males, and the two morphs had overlapping size distributions.

In animals, carotenoid-based color patterns such as the orange snouts of male *P. clathratus* are usually related to physical condition and foraging abilities, since carotenoids are acquired from food and are not synthesized (Endler 1983; Kodric-Brown 1989; Badyaev and Hill 2000). Moreover, variation in male coloration often plays an important role in female choice, where brightly colored males enjoy a higher reproductive success (Kodric-Brown 1983, 1998) than their dull-colored competitors. Both OS males and calico phase individuals were observed engaging in courtship and spawning events with females, however, the relative success of the two types of males was not investigated. Differences in the intensity and percent coverage of the orange coloration on the snouts of OS males was not quantified in this observational study. Further research into the specific characteristics of the snout coloration is necessary to determine whether such variations are important in female choice behavior and/or the reproductive success of male kelp bass.

Kelp bass spawn from 1900–2200 hrs, and the onset of spawning occurs at sunset (Erisman 2003). The high-contrast body color of male kelp bass was very noticeable during twilight, where the bright white spots became very conspicuous in low light conditions. Color patterns that contrast with a given background are believed to enhance the conspicuousness of courting males and increase the visibility of male courtship behavior in some fishes (Endler 1983; Neil 1984; Kodric-Brown 1998). Similar to the orange snout coloration, the high-contrast, gray and white courtship pattern exhibited by male *Paralabrax clathratus* may facilitate mate recognition and enhance courtship signaling in periods of low light and near darkness. In particular, it may increase the visibility of males and allow signaling to occur over greater distances. Although generally considered diurnal fishes, *P. clathratus* are known to also be active at night, and their scotopic visual pigments are well adapted to low-light conditions (Hobson et al. 1981).

The swollen, white abdomens and the dark coloration of gravid female kelp bass rendered them easily distinguishable from the courting males that surrounded them during spawning periods. Also, the head-up orientation of gravid females hovering in the water column may have increased the conspicuousness of their white abdomens to courting males. This type of female display behavior has been observed in several *Serranus* species (Clark 1965; Pressley 1981; Hastings and Petersen 1986). Similarly, Colin (1992) observed that female *Epinephelus striatus* with abdomens swollen with ova often adopted a conspicuous "white belly" color phase. During courtship and spawning in the coney, *Epinephelus fulvus,* females are identified by their white, distended bellies (Deloach 1999).

Given the high levels of activity and large numbers of aggregating adults during spawning periods, such dramatic color differences among males and females may be used to coordinate the formation of spawning subgroups in some serranids, including the kelp bass. During spawning, many female *Epinephelus striatus* adopt a black body or "dark phase", similar to that observed in some female *Paralabrax clathratus.* This color is often present in females leading presumed males during courtship and spawning events (Colin 1992).

The color patterns expressed by some male fishes may also assist in the deterrence of rival males, where they act as a warning signal of aggression and social status (Losey 1976; Neil 1984; DeMartini 1985). In the scamp, *Epinephelus phenax,* color phases are believed to reflect social status, with dominant males exhibiting a conspicuous grey-head color. Similarly, larger males often adopt this same coloration during courtship and aggressive bouts (Gilmore and Jones 1992). Aggressive interactions among courting male kelp bass were rare and rarely persisted for more than 5–10 seconds. Also, the marbled phase observed during some agonistic bouts was not observed in aggressive interactions that occurred during courtship and spawning. Rather, courting males retained the checkered phase during such encounters. Therefore, male courtship coloration may be less important in deterring rival males in kelp bass.

Many fishes exhibit color patterns that match their surroundings (Townsend 1929; Cott 1940). In some cases, this coloration is believed to enhance foraging by reducing their chances of being detected by prey (Hobson 1975; Moyer 1977; Endler 1983), whereas in many other fishes cryptic color patterns are believed to decrease the possibility of being detected by potential predators (Losey 1976; Endler 1978). Adult kelp bass varied significantly in body color patterns according to their habitat, generally exhibiting color patterns that made them less conspicuous in their environments. The cryptic coloration adopted by *Paralabrax clathratus* may function in both foraging and predator avoidance. Adult *P. clathratus* are generalized carnivores (Quast 1968) and utilize both ambush and stalking predatory behavior strategies (Hobson 1994; Hobson and Chess 2001). Camouflaged color patterns are likely to increase prey capture success rates by allowing individuals to get within striking distance of prey before being noticed. Similarly, these color patterns may also allow kelp bass to escape detection by larger predators, including conspecifics. The bright orange snouts of breeding male *P. clathratus* made them highly conspicuous to divers in all environments. It is possible that OS males are at greater risk to visual predators, although this hypothesis has not been tested.

The focus of our study was to describe the seasonal and ephemeral color patterns exhibited by adult kelp bass and the social and environmental contexts under which they occur. From our observations, it appears that many color patterns are uniquely associated with reproduction, and color patterns may play an important role in the spawning activity in *Paralabrax clathratus.* However, the specific functions of these color patterns can only be speculated upon until detailed experimental studies of mate choice and male-male interactions are conducted. Research on the spectral sensitivity of *P. clathratus* adults, including information on their photopic visual pigments, and the spectral structure of the various color patterns are necessary to determine how each of the color patterns are perceived. The visual system of fishes is quite different than that of humans, and proposing relationships between color patterns and behaviors using the human visual system often lead to erroneous conclusions (Marshall et al. 2003). Fishes vary greatly with respect to their visual sensitivity, and it is not known whether kelp bass can distinguish between the patterns and the colors described. Of particular importance is the orange snout coloration of male kelp bass, as red-sensitive visual pigments have not been found in other reef fishes (Losey et al. 2003; Marshall et al. 2003). However, red, yellow, and orange colors are common nuptial colors in many freshwater fishes, and these colors are especially common in fishes inhabiting turbid waters (Levine and MacNichol 1979; Kodric-Brown 1998).

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The Reef Fish Assemblage of the Outer Los Angeles Federal Breakwater, 2002–2003

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Abstract.—The conspicuous and cryptic fish assemblage of the Los Angeles Federal Breakwater was assessed from 2002 to 2003. Thirty-five species were observed or collected during the study period. The assemblage of cryptic fishes was composed primarily of a mix of Oregonian and San Diegan, species including snubnose sculpin (*Orthonopias triacis*), coralline sculpin (*Artedius corallinus*) and blackeye goby (*Rhinogobiops nicholsii*). The species composition of conspicuous fishes was approximately equal between taxa from these two provinces. Blacksmith (*Chromis punctipinnis*), black perch (*Embiotoca jacksoni*) and kelp bass (*Paralabrax clathratus*) dominated the assemblage of conspicuous fishes. Species composition reflects the localized cool temperature regime of the area and the high relief kelp forest habitat.

Rocky reefs are among the most important but least abundant habitats within the Southern California Bight (Cross and Allen 1993). More than 125 species of fish have been documented in this habitat, more than 25% of the Californian marine total (Quast 1968b; Feder et al. 1974; Horn and Allen 1978). Artificial reefs have been constructed within the Bight to augment natural reefs and to mitigate lost natural reefs through development or habitat degradation (Ambrose 1994). Although not their primary purpose, breakwaters form artificial reefs and have been shown to be effective fish enhancement structures in urban areas (Stephens et al. 1994). Breakwaters provide high relief, complex habitats that are ideal for many reef-associated fishes. The Los Angeles Federal Breakwater is 13.8 km long (McQuat 1951) making it the largest artificial reef in the Southern California Bight, yet, prior to this study, a systematic characterization of the fish population on this breakwater has not been made. The breakwater at King Harbor, Redondo Beach, California has been extensively surveyed since 1974, and more than 100 species of fish have been observed with about half of those being resident (present year-round throughout the study) species (Stephens and Zerba 1981; Stephens et al. 1994). However, this breakwater is also characterized by a high degree of temperature stratification due to warm water input from a coastal generating station into King Harbor and its proximity to the Redondo submarine canyon. King Harbor, a small craft marina, is also probably less affected than Los Angeles Harbor, a major international port, by anthropogenic effects. Quantitatively evaluating the fish assemblage on Los Angeles Federal Breakwater will provide critical information on the potential of these structures to replace or supplement natural rocky reef habitat in an urban setting.

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Artificial reefs have been shown to support high densities of fish due to either attraction or production of fishes, but generally have low standing stocks compared to natural reefs because artificial reefs are generally smaller than natural reefs (Ambrose and Swarbrick 1989; Demartini et al. 1989). Monitoring of reef fishes has become an important component of many fisheries management strategies to ensure maintenance of "healthy" ecosystems and sustainable fisheries (Stephens and Zerba 1981; Stephens et al. 1984; Paddack and Estes 2000). This task is especially important in areas that are near large population centers and/or are heavily influenced by anthropogenic activities.

Visual censuses along transects with defined widths and lengths can be used to make reasonably accurate estimates of the density of fishes, and their effectiveness has been well established for fishes on temperate reefs in southern California (e.g. Quast 1968a, b, c; Ebeling et al. 1980; Stephens and Zerba 1981; Larson and DeMartini 1984; Stephens et al. 1986; DeMartini et al. 1989; Allen et al. 1992). However, visual censuses tend to underestimate fish densities (Sale and Douglas 1981) especially those of small or cryptic species (Brock 1982; Bellwood and Alcala 1988). These limitations are generally well recognized and do not prevent reasonably precise density estimates for conspicuous fishes from being obtained.

Cryptic fishes are usually small, camouflaged fishes that live in or among rocks, crevices, or algae. These fish usually retreat into the reef in the presence of divers and thus cannot be accurately sampled using techniques for estimating densities of conspicuous fishes. Cryptic fishes are more precisely estimated with the use of ichthyocides or anesthetics (Allen et al. 1992). Previous studies in southern California have shown cryptic fishes to be important members of rock reef habitats in terms of density, species richness (Allen et al. 1992), and secondary productivity (Stephens and Zerba 1981; Stephens et al. 1984).

The primary goal of this study was to provide a description of the reef fish assemblage of the outer Los Angeles Federal breakwater using visual census and an anesthetic to survey both large mobile and small cryptic fishes effectively. The densities, depth distributions, biomass and seasonality of the fish assemblage were determined.

Methods

The Los Angeles Federal Breakwater forms the western border of the Los Angeles-Long Beach Harbor complex (Figure 1). The Breakwater was constructed in three parts. The northernmost section was completed in 1912 and the final two sections were completed in 1928 (McQuat 1951). It is constructed of quarry rock that forms a sloping high relief reef extending from the surface to 15 meters where it is bounded by a mud flat (J.T.F. personal observation). During this study purple urchins (*Strongylocentrotus purpuratus*) forming characteristic barrens dominated the shallow subtidal portion of the reef (< 4 m). Giant kelp (*Macrocystis pyrifera*) was abundant between 5–10 m throughout the study, while coralline algae and macroinvertebrates dominated the deeper portions of the reef.

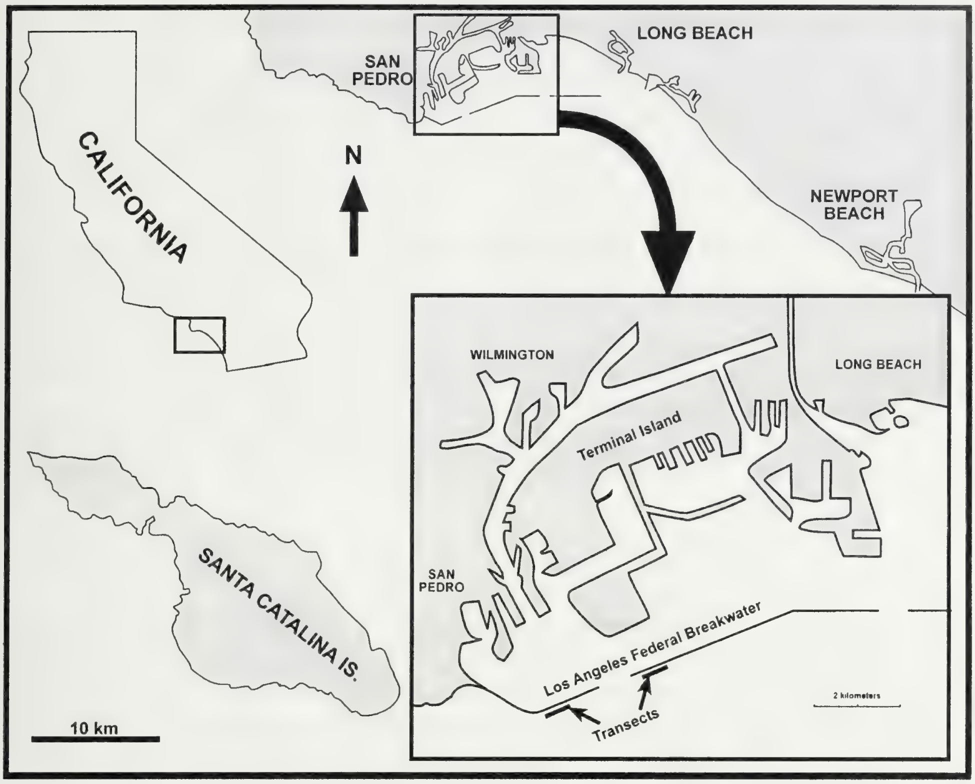
SAN PEDRO
LONG BEACH
CALIFORNIA
N
NEWPORT BEACH
SANTA CATALINA IS.
10 km
WILMINGTON
LONG BEACH
Terminal Island
SAN PEDRO
Los Angeles Federal Breakwater
Transects
2 kilometers

Fig. 1. Location of the study sites at the Los Angeles Federal Breakwater.

Sampling

Cryptic and conspicuous fishes were sampled quarterly from September 2002 to November 2003 at two sites along the outer Breakwater (Figure 1). Fishes were not sampled in Spring 2003 due to poor visibility and severe wave action at the study site. Conspicuous fishes were censused using visual transects on SCUBA at randomly selected 6 m and 12 m isobaths. All transects were conducted between 1000 and 1400 hrs. On each sampling date, divers swam a 2 m wide × 50 m long transect counting all conspicuous fishes within the 100 m^2 area. Counts made by two divers were averaged for each transect. All fishes that passed divers from behind were omitted to avoid counting the same fish multiple times or overestimating fishes that may be attracted to divers (Terry and Stephens 1976; Stephens and Zerba 1981; Stephens et al. 1984). Four replicate transects were conducted at each depth at two sites each sampling period, except January 2003 where two replicates per depth per site were completed due to poor visibility.

Cryptic fishes were sampled in 1 m^2 randomly selected quadrats using quinaldine diluted 1:9 in 2-propanol. All fish within the 1-m quadrat were anesthetized and collected in mesh bags, fixed in 10% formalin for seven days and preserved in 70% ethanol. A minimum of four replicates per depth per site was taken during each sampling period to assess abundance and species composition. Specimens were blotted dry and weighed to the nearest 0.1 gram (wet weight; WWT) and standard length (SL) was measured to the nearest 0.1 mm in the laboratory using digital calipers.

Biomass of conspicuous fishes was estimated by determining an average length of every species from each age class and then using established length-weight regressions for each species. Cryptic species that were observed on transects were estimated by taking the mean weight of that species from cryptic collections taken during this study.

The effects of depth and sampling date (season) on density and biomass were tested using two-way analysis of variance (ANOVA) with replication. Data were log $(x + 1)$ transformed for conspicuous fishes, and log $(x + 1/6$ of the minimum non-zero value) transformed for cryptic fishes to restore normality and homoscedasticity to these data. However, it is important to note that this study occurred on a single continuous reef. Therefore, depth is also confounded with changes in habitat between depths and that seasonal effects may not have been adequately sampled. These factors should be considered when interpreting these data.

Results

Cryptic Fishes

A total of 107 individuals were collected in 62 1-m^2 samples. Thirteen species from eight families were collected over the study period. The assemblage of cryptic fishes consisted primarily (82.2%; Table 1) of three species, snubnose sculpin (*Orthonopias triacis*), coralline sculpin (*Artedius corallinus*) and blackeye goby (*Rhinogobiops nicholsii*). Snubnose sculpin was the most abundant species (37%) followed by coralline sculpin (23.4%) and blackeye goby (18.7%).

Density (individuals/m^2) of all cryptic fishes during the study period was 1.8 $m^2 \pm 0.16$ ($n = 62$). The density of all species combined was highest in July 2003, (Figure 2) and lowest in January 2003 although differences in density among seasons were not statistically significant (ANOVA, $F_{3,58} = 0.59$; $P = 0.62$). The density within the individual depth strata did not closely follow the trend of the combined depth strata. The highest density was recorded in shallow stratum in July 2003, the lowest density in October 2002, and intermediate density in November 2003. Overall, mean density was higher in the shallow stratum but was not significant (ANOVA, $F_{1,46} = 0.8$; $P = 0.37$). The shallow stratum was not sampled in January 2003 due to strong surge, which prevented accurate surveys at shallow depths. The fish density peaked in the deep stratum in October 2002 and November 2003, with the lowest density encountered in January 2003. The number of species remained relatively constant over the sample period, ranging from a low of five in January of 2003 to a maximum of seven in October 2002 and July 2003.

Mean biomass (gWWT/m^2) of all cryptic fishes during the study period was 3.3 ± 0.82 ($n = 62$; Figure 3). Biomass closely paralleled the trend of density. It was highest in July and November of 2003 and lowest in January 2003 and there was no significant difference in biomass density between depths (ANOVA, $F_{1,46} = 1.7$; $P = 0.20$) or among seasons (ANOVA, $F_{2,46} = 0.1$; $P = 0.94$). Blackeye goby constituted the most biomass, comprising 18.7% of the total, although this species was ranked fourth in terms of numerical density (Table 1). Painted greenling (*Oxylebius pictus*) was ranked second in terms of biomass comprising

Table 1. Density and biomass of individuals collected in five quarterly surveys of cryptic fishes at the outer Los Angeles federal breakwater, from October 2002 to October 2003. Biomass (gWWT/m^2) indicated in parentheses.

Species	Common name	October 2002	January 2003	July 2003	November 2003	Total	%
Orthonopias triacis	Snubnose sculpin	14 (7.6)	5 (8.3)	16 (7.2)	8 (10.7)	43 (33.7)	40.7 (17.0)
Artedius corallinus	Corraline sculpin	4 (4.3)	3 (4.6)	9 (5.3)	9 (12.2)	25 (26.5)	23.4 (13.4)
Rhinogobiops nicholsii	Blackeye goby	11 (13.9)	1 (0.9)	1 (2.0)	7 (20.1)	20 (37.0)	18.7 (18.7)
Gibbonsia elegans	Spotted kelpfish	3 (10.3)		2 (4.7)		5 (15.1)	4.7 (7.6)
Alloclinus holderi	Island kelpfish		1 (1.0)		2 (5.7)	3 (6.8)	2.8 (3.4)
Gobiesox rhessodon	California clingfish			3 (4.7)		3	2.8 (2.4)
Oxylebius pictus	Painted greenling			2 (34.3)		2	1.9 (17.3)
Chromis punctipinnis	Blacksmith	1 (0.4)				1 (0.4)	0.9 (0.2)
Lythrypnus zebra	Zebra goby	1 (0.5)				1 (0.5)	0.9 (0.3)
Scorpaena guttata	California scorpionfish	1 (19.6)				1 (19.6)	0.9 (9.9)
Sebastes atrovirens	Kelp rockfish			1 (2.7)		1	0.9 (1.4)
Sebastes auriculatus	Brown rockfish				1 (7.3)	1 (7.3)	0.9 (3.7)
Sebastes carnatus	Gopher rockfish				1 (9.4)	1 (9.4)	0.9 (4.8)
	Total	35	10	34	28	107 (375.5)	
	Density no./m^2	1.8	1.2	2.1	1.8	1.7	
	Biomass (gWWT/m^2)	(2.8)	(1.5)	(3.8)	(4.1)	(3.1)	
	Number of species	7	4	7	6	13	

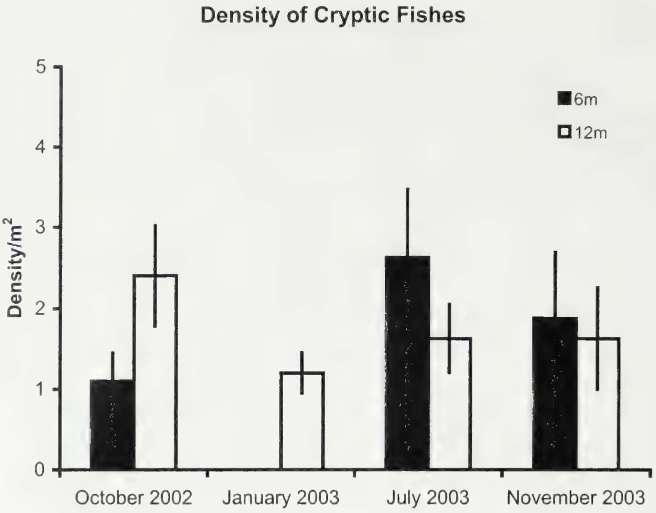

Fig. 2. Mean density of cryptic fishes at six and twelve meter depth strata at the Los Angeles Federal Breakwater. Density varied significantly by season in the six meter stratum (ANOVA $F_{3,23}$ = 17.45, $P < 0.001$) although seasonal variation in the deep stratum was not significant (ANOVA $F_{3,32}$ = 1.11; P = 0.36).

17.3% of the total (Table 1) although only two large individuals were collected during the study. Snubnose sculpin was numerically dominant but third most abundant in biomass (17.0%). Three species of juvenile rockfish, kelp rockfish, brown rockfish and gopher rockfish (*Sebastes atrovirens, S. auriculatus* and *S. carnatus* respectively) contributed disproportionately to the biomass total contributing 9.8% of the total biomass although only three large individuals were collected. Six families accounted for 97.4% of the total biomass and were dominated

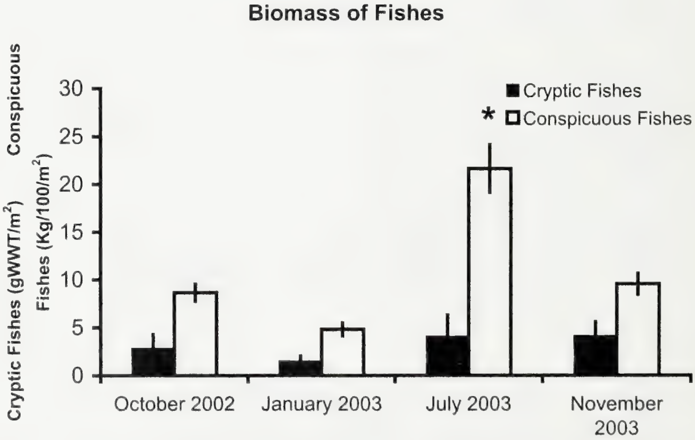

Fig. 3. Biomass density of cryptic and conspicuous fishes for two depth strata combined, by season, over the period of October 2002 to November 2003. There was no significant difference in biomass of cryptic fishes between depths (ANOVA $F_{1,46}$ = 1.4; P = 0.24) or among seasons (ANOVA $F_{2,46}$ = 0.3; P = 0.76). A significant peak in biomass density of conspicuous fishes occurred in July 2003 (ANOVA, $F_{3,52}$ = 18.8; $P < 0.001$; Tukey post hoc test; $P < 0.001$). Results shown as mean ± SE.

by Cottidae (30.4%), Scorpaenidae (19.7%), Gobiidae (18.9%), Hexagrammidae (17.3%), Clinidae (7.6%) and Labrisomidae (3.4%).

Conspicuous Fishes

Twenty-eight species from 13 families were observed on 56 transects during the study period (Table 2). Five species accounted for 80.8% of all fishes counted on visual transects during the study. These included blacksmith (*Chromis punctipinnis*; 56%), black perch (*Embiotoca jacksoni*; 12%), pile perch (*Rhacochilus vacca*; 6%), kelp bass (*Paralabrax clathratus*; 3.5%) and señorita (*Oxyjulis californica*; 3.3%). Large schools of blacksmith juveniles were often observed. The density of the top five species remained relatively constant during the study.

The mean density of conspicuous fishes was 85.3 ± 7.1/100 m^2 ($n = 56$). Patterns of density were similar between the depth strata except in October 2002 when juvenile blacksmith recruited in large numbers (Figure 4). Fishes were significantly more abundant in shallow depths throughout the study period (ANOVA, $F_{1,48} = 21.4$; $P < 0.001$). Density also varied significantly by season in the shallow stratum (ANOVA, $F_{3,23} = 17.45$; $P < 0.001$) and was significantly higher in July 2003 (Tukey post hoc test; $P < 0.05$). The peak density in the shallow stratum during summer was primarily due to the abundance of juvenile blacksmith that recruited during that period. Variation in density at the deep strata over time was marginally significant (ANOVA, $F_{3,23} = 2.72$; $P = 0.07$; Figure 4). Abundance in the deep stratum showed a similar pattern of seasonal variation, despite the absence of the juvenile blacksmith.

Mean biomass (Kg/100 m^2) of all conspicuous fishes during the study period was 12.1 ± 1.16 ($n = 56$; Figure 3) and closely followed the pattern of density. Biomass was significantly higher in the shallow stratum (ANOVA, $F_{1,54} = 7.5$; $P = 0.008$), and a significant peak in biomass density occurred in July 2003 (ANOVA, $F_{3,52} = 18.8$; $P < 0.001$; Tukey post hoc test; $P < 0.001$).

The density (individuals/100 m^2) of cryptic fishes contributed substantially to the overall density of cryptic and conspicuous fishes. The mean density of cryptic fishes combined across depths was 174 ± 21.7 ($n = 62$) compared to 85 ± 7.1 ($n = 56$) for conspicuous fishes increasing the total density of fishes 300% and constituting 67% of the total density. Six species were observed both on visual transects and in cryptic collections (Table 3). Species richness was increased from 28 to 35 species (an increase of 25%) with the inclusion of cryptic fishes; however the increase in biomass was minimal (< 10%).

Discussion

Species richness of cryptic fishes from the Los Angeles Breakwater was comparable to that found in other studies of rocky reef habitats. In this study, 13 species of cryptic fishes were collected in 62 benthic samples. This is comparable to 12 species in 60 samples at King Harbor (Stephens and Zerba 1981), nine species in 20 samples at Palos Verdes (Stephens et al. 1984) and 14 species in 105 samples using rotenone enclosures at Santa Catalina, Island, California (Allen et al. 1992). In comparison, 28 species were observed during 56 visual transects at the Los Angeles Breakwater during the same period. A mean of 9.6 ± 0.31 ($n = 56$) species per transect were observed, similar to the 7–12 species per 100 m^2 transect reported by Stephens et al. (1994) at King Harbor, California.

Table 2. Density of conspicuous fishes (100 m^2) surveyed on 56 visual transects from October 2002 to November 2003. Results are presented as mean ± standard error.

Family	Species	Common name	October 2002	January 2003	July 2003	November 2003	Total
Pomacentridae	*Chromis punctipinnis*	Blacksmith	61.3 ± 7.8	27.6 ± 4.9	84.3 ± 15.7	9.1 ± 2.8	45.6 ± 2.8
Embiotocidae	*Embiotoca jacksoni*	Black perch	6.6 ± 1.4	7.4 ± 1.3	10.4 ± 1.4	14.9 ± 2.2	9.8 ± 0.2
Embiotocidae	*Rhacochilus vacca*	Pile perch	3.7 ± 0.5	5.0 ± 0.7	3.3 ± 0.4	6.8 ± 1.1	4.7 ± 0.1
Serranidae	*Paralabrax clathratus*	Kelp bass	1.2 ± 0.5	1.0 ± 0.3	4.4 ± 0.1	4.3 ± 0.8	2.7 ± 0.2
Labridae	*Oxyjulis californica*	Senorita	3.1 ± 1.0	2.3 ± 0.4	1.5 ± 0.6	3.9 ± 0.8	2.7 ± 0.1
Embiotocidae	*Brachyistius frenatus*	Kelp perch	1.1 ± 0.5	1.0 ± 0.7	2.0 ± 1.0	5.4 ± 1.6	2.4 ± 0.2
Kyphosidae	*Hermosilla azurea*	Zebraperch	0.1 ± 0.1		7.1 ± 3.3		1.8 ± 1.1
Labridae	*Semicossyphus pulcher*	California Sheephead	1.4 ± 0.6	0.8 ± 0.2	1.4 ± 0.6	1.6 ± 0.4	1.3 ± 0.1
Hexagrammidae	*Oxylebius pictus*	Painted greenling	1.8 ± 0.3	0.8 ± 0.3	1.6 ± 0.4	0.9 ± 0.2	1.3 ± 0.0
Kyphosidae	*Girella nigricans*	Opaleye	0.2 ± 0.1	0.1 ± 0.1	3.3 ± 1.4	0.8 ± 0.3	1.1 ± 0.3
Serranidae	*Paralabrax nebulifer*	Barred sand bass	1.4 ± 0.4	0.8 ± 0.6	2.1 ± 0.3	0.4 ± 0.2	1.2 ± 0.1
Pomacentridae	*Hypsopops rubicundus*	Garibaldi	0.6 ± 0.3		1.2 ± 0.4	1.6 ± 0.5	0.9 ± 0.1
Kyphosidae	*Medialuna californiensis*	Halfmoon	0.1 ± 0.1	0.3 ± 0.3	0.1 ± 0.1	2.9 ± 1.5	0.8 ± 0.3
Scorpaenidae	*Sebastes serranoides*	Olive rockfish	5.1 ± 3.4	0.8 ± 0.6		0.4 ± 0.2	1.5 ± 0.9
Labridae	*Halichoeres semicinctus*	Rock wrasse	0.7 ± 0.3		1.0 ± 0.3	0.9 ± 0.3	0.6 ± 0.0
Embiotocidae	*Rhacochilus toxotes*	Rubberlip seaperch	1.9 ± 0.7	0.3 ± 0.3	0.3 ± 0.1	0.4 ± 0.2	0.7 ± 0.1
Scorpaenidae	*Sebastes atrovirens*	Kelp rockfish	2.0 ± 0.7		0.4 ± 0.2		0.6 ± 0.2
Gobiidae	*Rhinogobiops nicholsii*	Blackeye goby	0.9 ± 0.3		0.3 ± 0.1	0.4 ± 0.2	0.4 ± 0.0
Embiotocidae	*Hypsurus caryi*	Rainbow seaperch	0.1 ± 0.1	1.9 ± 0.8	0.2 ± 0.2	0.3 ± 0.1	0.6 ± 0.2
Clinidae	*Heterostichus rostratus*	Giant kelpfish	0.1 ± 0.1			1.1 ± 0.4	0.3 ± 0.1
Haemulidae	*Anisotremus davidsonii*	Sargo			0.2 ± 0.1	0.3 ± 0.2	0.1 ± 0.0
Labrisomidae	*Alloclinus holderi*	Island kelpfish	0.1 ± 0.1		0.3 ± 0.2		0.1 ± 0.0
Embiotocidae	*Phanerodon furcatus*	White seaperch	0.3 ± 0.3				0.1 ± 0.1
Scorpaenidae	*Scorpaena gutata*	Spotted scorpionfish	0.1 ± 0.1				0.0 ± 0.0
Cottidae	*Scorpaenichthys marmoratus*	Cabezon		0.1 ± 0.1		0.1 ± 0.1	0.0 ± 0.0
Scorpaenidae	*Sebastes chrysomelas*	Black and yellow rockfish	0.1 ± 0.1			0.1 ± 0.1	0.0 ± 0.0
Heterodontidae	*Heterodontus francisci*	Horn shark		0.1 ± 0.1			0.0 ± 0.0
Scorpaenidae	*Sebastes serriceps*	Treefish			0.1 ± 0.1		0.0 ± 0.0

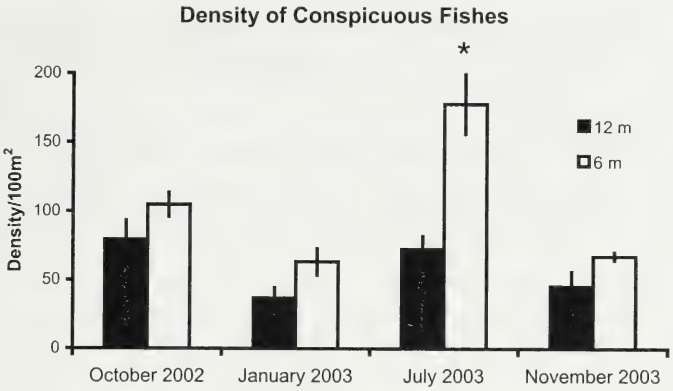

Fig. 4. Density of conspicuous fishes at six and twelve meter depth strata. Density varied significantly by season 6m ANOVA $F_{3,23} = 17.45$, $P < 0.001$. Variation in density at the deep strata was not significant. Results shown as mean ± SE.

Density varied seasonally in a similar manner with both the cryptic and conspicuous fishes at the Federal Breakwater. The density of both conspicuous and cryptic fishes peaked during the summer of 2003 corresponding to the warmest period of the study. The density of the five most abundant conspicuous species were relatively constant throughout the study suggesting that these species are all permanent residents of the reef. Blacksmith is a warm temperate species that has been the dominant planktivore in most southern rocky reef kelp bed environments since 1976–1977 when sea surface temperatures in southern California began to increase (Stephens and Zerba 1981). This species depends on high relief reef for shelter during nocturnal periods and is well suited to breakwaters because of the high availability of caves and crevices used at night.

Six species of surfperches (Embiotocidae) were observed during this study and comprised 21% of all fishes counted. After the blacksmith, the black and pile perch were the most abundant fishes. These surfperches are unique in that they are non-dispersing livebearers who are dependent upon the resources of the reef they inhabit making them excellent models for examining reef productivity (Ellison et al. 1979; Schmitt and Holbrook 1990; Pondella et al. 2002). As such, annual year-class strength of newborn surfperches was tightly coupled to habitat productivity in Santa Barbara, California (Holbrook et al. 1997). Abundance of black and pile perch were higher than reported at King Harbor and much higher than the density at Palos Verdes, Rancho Palos Verdes, California, the nearest rocky reef (Pondella et al. 2002). The relatively high density of these demersal surfperches was an indication of overall reef production and health.

Overall, few differences were apparent in the distribution of fishes between the shallow and deep strata. The shallow portions of the breakwater had higher densities of conspicuous fishes that were largely driven by the presence of juvenile blacksmith. No trend in densities of cryptic fishes with depth was observed. However, cryptic fishes were extremely rare in the urchin barrens that dominated the shallow regions of the reef (J.T.F, pers. observ.). Two species of sculpins (Cottidae) collected in the study were more abundant in areas with fleshy red algae or areas protected from physical disturbance. Exposed areas and areas dominated with coralline algae often had few or no cryptic fish present. It appears that wave action may prevent cryptic fishes from inhabiting the most exposed habitats when appropriate shelter is absent.

Fishes collected in cryptic samples consisted of both small camouflaged forms and juvenile benthic fishes including three species of rockfishes and the painted greenling. The small cryptic fishes consisted primarily of three species, which contributed 82% of the total individuals and 49% of the biomass. Overall, cryptic fishes increased the total numerical density estimate of the reef by 300% while their contributions to total biomass are less than ten percent. However, these fishes have a high turnover rate and may serve as important prey items to other fishes constituting an important component of energy transfer in reef ecosystems.

Many studies have attempted to discern the factors that influence fish assemblages in particular habitats. Artificial reefs in particular received a great deal of attention because they are often used as mitigation tools to replace lost habitat. In order to mitigate lost habitat effectively they must replace natural reefs in terms of species composition and biomass. Most studies comparing artificial and natural reefs have found general similarity in the fish assemblages (Russel 1975; Jones and Thompson 1978; Molles 1978; Matthews 1985). Studies have also reported higher densities of fish on artificial reefs than on natural reefs (Ambrose and Swarbrick 1989; Pondella et al. 2002). Some characteristics that influence temperate fish assemblages include temperature regime, recruitment success (Stephens et al. 1994) and algal cover (Holbrook et al. 1990). Stephens et al. (1984) suggested that temperature change is the most important factor controlling changes in the kelp-rock fish assemblage. Over the past three decades the Southern California Bight has warmed appreciably and Oregonian species have declined in this region. However, on a localized scale a persistent influence of cool water can support these species, a process that has been noted on the Pacific coast of Baja California (Horn and Allen 1978; Pondella et al. 2005).

The Los Angeles Federal Breakwater supports a diverse and abundant reef fish assemblage. Species richness and density were at or above comparable artificial and natural reefs. The persistent cool water of this area influences these factors. The largest artificial reef in Southern California, which borders the third busiest commercial port in the world, supports a healthy and robust ichthyofauna.

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Structure and Composition of the Polychaete Community from Bahia San Quintin, Pacific Coast of Baja California, Mexico

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Abstract.—The diversity patterns of the polychaete fauna from a Pacific coastal lagoon were described. Polychaetes were collected in 1995 and 1998. This lagoon is formed by 2 arms: the western arm named Bahia Falsa and the eastern arm named Bahia San Quintin. 46 stations were sampled with a geological box corer. A total of 3,275 polychaetes, 28 families, 56 genera, and 104 species were identified in 1995, and 3,168 polychaetes were collected in 1998, 21 families, 39 genera and 65 species. From all the macrofauna collected in both surveys, polychaetes represented 45.2%. From the species collected, 55% correspond to new records for the area. Families Dorvilleidae, Polynoidae, Oweniidae, Scalibregmatidae, Sternapsidae and Sigalionidae present in 1995, were not in 1998 survey.

The stations with higher abundances (> 100 specimens/0.02 m^2) were located on the southern half of Bahia San Quintin. Species richness and diversity were also higher in San Quintin Bay. From the 30 families previously reported for San Quintin lagoon, 23 have been collected and 6 families were added: Ampharetidae, Oweniidae, Scalibregmatidae, Sternapsidae, Dorvilleidae and Sigalionidae. Families not found in both surveys were: Paraonidae, Magelonidae, Apistobranchidae, Sphaerodoridae, Trichobranchidae, Chrysopetalidae and Arenicolidae.

Results showed slightly lower redox potential values (−336 to +187 mV), slightly higher sediment temperatures (19.8°–22.1°C) and organic matter contents (0.3–4.1%) in 1998.

From 1995 to 1998 a change in the composition and structure of the polychaete communities was noted; species richness diminished from 104 to 65 species. The trophic complexity changed with an increase of deposit-feeders, the abundance of other trophic categories decreased, indicating a loss of complexity. Significant changes in the abundance of some families were detected, some increased their abundances: Spionidae from 17% to 48%, Orbiniidae from 4% to 13%; other families decreased in terms of abundance and number of species: Lumbrinereidae from 11% to 1.4%, Nereididae from 9% to 1% and Sabellidae from 14% to 5%. These modifications altered the composition and structure of the polychaete communities in this lagoon. Increased anthropogenic disturbance (oyster culture, agriculture) and environmental variability due to the ENSO 97–98 may have affected recruitment and survival of some polychaete species.

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Introduction

Some lagoons, located along the Pacific coast of Mexico, present ideal hydrological and sedimentary characteristics which make them potential sites for aquaculture. The San Quintin complex is one of these coastal lagoons that favor the development of bivalve aquaculture. It is considered ecologically important because it is a nursery area for several fish species, a resting site for migrating birds which have lost most of their resting and feeding areas in the United States, and its high productivity and diversity, in part due to upwellings which supply nutrients periodically. It is environmentally important to obtain baseline scientific data that help understand how benthic communities function and how they change during different climatological conditions.

The hydrology of San Quintin lagoon has been studied (Alvarez-Borrego & Chee-Barragán 1976; Alvarez-Borrego et al. 1975; del Valle & Cabrera-Muro 1981 a, b; Farfán & Alvarez-Borrego 1983). In contrast, there is a lack of information on macrofauna. One of the most neglected, major groups of marine invertebrates may be the polychaetous annelids that could be useful as indicators of varying degrees of marine pollution (Tsutsumi 1990; Pocklington & Wells 1992). Only three polychaete surveys were found on the literature: Reish (1963) 90 stations sampled in 1960 in Bahía San Quintín (BSQ eastern arm), Calderón-Aguilera & Jorajuría-Corbo (1986) 11 stations sampled in 1981–82, 8 in BSQ and 3 in Bahía Falsa (BF western arm); and Díaz-Castañeda & Rodríguez Villanueva (1998) 39 stations sampled in December 1992, 13 in BF and 26 in BSQ.

Coastal marine benthic communities are threatened by human activities, and the present rate of habitat degradation is alarming. Given that only a small fraction of the benthic organisms that reside on or are buried in sediments have been described, it is likely that species are being lost without ecologists knowing they existed (Snelgrove 1999). Polychaetes constitute an important macrofaunal group in this lagoon comprising about 70% of the benthic biomass and individuals (Barnard 1970; Calderón-Aguilera & Jorajuría-Corbo 1986). More than 1,450 polychaete species are known from Mexico (Salazar-Vallejo et al. 1989; Díaz-Castañeda & Rodríguez-Villanueva 1998). Polychaetes are a significant component of all marine ecosysytems, they dominate soft-bottoms communities in terms of numbers of species and individuals. These annelid worms are important in food webs and in energy transference, both as predators and as important prey items for other animals, including crustaceans, fish and wading birds (Knox 1960). They present different feeding modes (carnivores, herbivores, omnivores, deposit-feeders, symbiotic chemoautotrophic bacteria), this plasticity could be the reason of their success in many environments (Beesley et al. 2000). Many species are important bioturbators of sediment and facilitate the incorporation of organic matter into sediments. Polychaetes show a spectacular diversity of reproductive and developmental modes which allow them to live in different environments (Wilson 1991; Giangrande 1997). Because of their cosmopolitan distribution, polychaetes can be used as indicators of pollution and the "state of health" of a benthic community (Pearson & Rosenberg 1978; Reish 1980; Bellan et al. 1988; Pocklington & Wells 1992; Lardicci & Rossi 1998).

From a management perspective, they are useful organisms for identifying problem sites and for the assessment of the severity of the problem. They respond to disturbance induced by different kinds of pollution, by exhibiting quantitative changes in assemblage distribution. Polychaetes can also be used as indicators of recovery of benthic environments from perturbations since in many cases they are major elements of the recolonization process (Díaz-Castañeda et al. 1989; Díaz-Castañeda & Almeda-Jauregui 1999).

In spite of their importance in benthic communities few faunal studies have occurred in Mexico, in part because of identification problems due to lack of proper identification keys as well as the low number of polychaetologists (Salazar-Vallejo et al. 1989; Pocklington & Wells 1992).

El Niño is an important phenomenon throughout the world. Its effects on marine ecosysytems and organisms may go beyond temperature change. Invertebrates have complex life cycles in which certain life stages, and therefore the dynamics of entire populations, are at the mercy of various physical processes acting within the ocean-atmosphere system (Arntz & Tarazona 1990; Bakun 1996; Escribano et al. 2004). During El Niño Southern Oscillation (ENSO) 1997–1998, high temperatures and low nutrient concentrations resulted in widespread mortality of giant kelp forests (*Macrocystis pyrifera*) (Tegner & Dayton 1987) and other marine organisms in the region. Temperature anomalies greater than 1°C persisted continuously for 8 months in the west coast of Baja California, in some cases anomalies attained +3°C (Dayton et al. 1992).

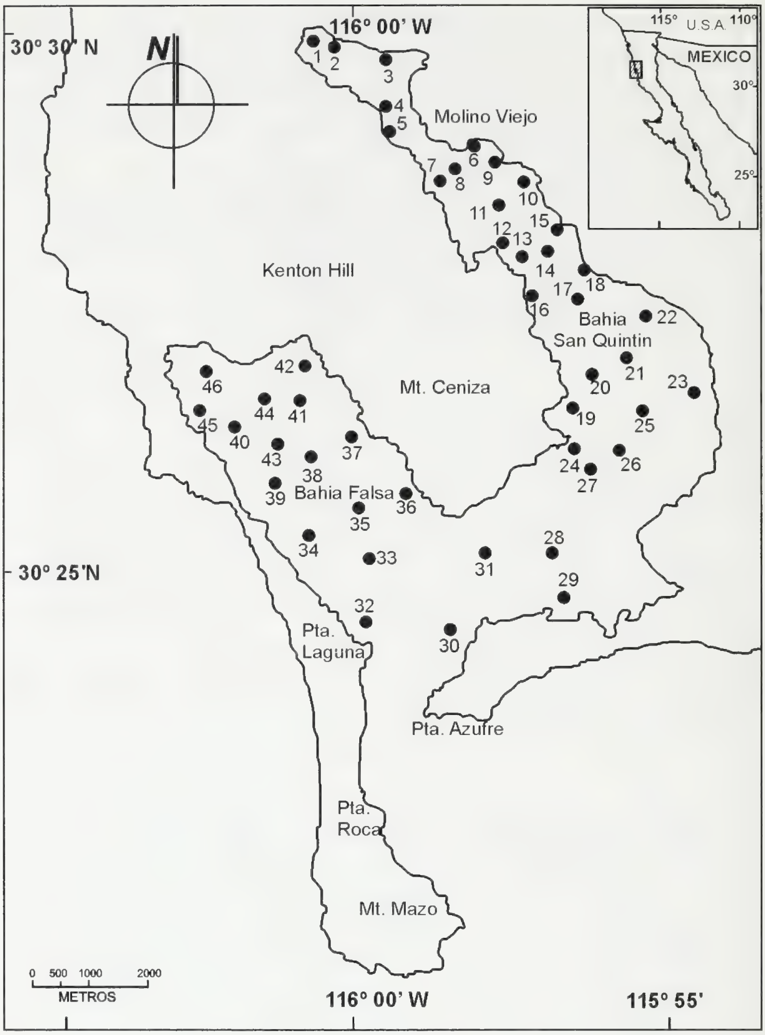
The purpose of this study is to describe the composition and structure of polychaete communities in San Quintín lagoon in 1995 and 1998 before and after the El Niño 1997–98.

Study Area

San Quintin complex is a slightly hypersaline, highly productive coastal lagoon located between 30°24′–30°30′ N and 115°57′–116°01′ W in the Pacific coast of Baja California (Fig. 1). This lagoon has an area of 42 Km^2 (4,200 hectares) and around 80% of it is covered by the eelgrass *Zostera marina* (Inclán-Rivadeneyra & Acosta-Ruiz 1988; Poumian-Tapia & Ibarra-Obando 1999). It has been exploited for many years (mariculture) but it can still be considered a relatively non disturbed area, although oyster culture is increasing. The region is arid, with a mean annual rainfall of about 150 mm. About 90 percent of the rainfall occurs between October and March.

Seagrass beds are important nursery areas for many species of fish and invertebrates, including several of economic importance (Stoner 1980 a, b; Orth & van Montfrans 1984, 1990). They also help to stabilize sediments thus reducing coastal erosion and are responsible for the composition and diversity of the seagrass infauna.

The lagoon has the shape of an inverted "Y", it consists of two sub-basins: BF (west) and BSQ (east). BF has an average depth of 4 m whereas BSQ has an average depth of 8 m. The bay has extensive intertidal and shallow subtidal shoals and channels up to about 10 m deep extending along the length of each basin. It has a permanent entrance and exchanges water with the coastal ocean. During low tides around 20% of the seafloor is exposed. An important aspect of the marine environment is the pattern of coastal upwelling, which is strongest between May and August (Aguirre-Muñoz et al. 1999). The granulometric studies show that in shallow areas as well as to the north of both arms clay and silty-sand


30° 30' N
N
116° 00' W
115° U.S.A. 110°
MEXICO
30°
25°
1
2
3
4
5
Molino Viejo
6
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Kenton Hill
Bahia San Quintin
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Bahia Falsa
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35
34
33
Mt. Ceniza
28
31
29
30° 25'N
32
Pta. Laguna
30
Pta. Azufre
Pta. Roca
Mt. Mazo
0 500 1000 2000
METROS
116° 00' W
115° 55'

Fig. 1. Location of San Quintin lagoon on the Pacific coast of Baja California and sampling stations.

predominate, whereas near the mouth very fine sands are more abundant. The channel sediments are highly diverse, going from medium to fine sand and silt (Calderón-Aguilera 1992; Camacho-Ibar et al. 1997; Poumian-Tapia & Ibarra-Obando 1999). The lagoon margins present a typical saltmarsh flora with *Spartina foliosa* and *Salicornia virginica* and other vascular plants (Dawson 1962; Barnard 1970).

Material and Methods

Forty six stations were sampled in December 1995 and April 1998, including 15 stations in BF and 31 in BSQ (Fig. 1). Samples were collected using a box corer (16 cm internal diameter, 13 cm depth, sampling area of 0.02 m^2). Temperature and redox potential were measured immediately after collection of each sample by probing 2–3 cm inside the sediments an electrode coupled to a field potentiometer and a thermometer. Sediments were sieved in the field using a 1.0 mm mesh size and retained material was fixed in 10% buffered formaldehyde. In the laboratory, samples were washed and transferred to 70% isopropanol. Different zoological groups and particularly polychaetes were then sorted and identified at species level whenever possible.

Organic matter (percent of dry weight) was evaluated by ignition loss (Byers et al. 1978). Statistical methods were used to describe the structure and organization of the polychaete communities within the bay. Shannon diversity index and Pielou equitability were calculated in order to study the structure and degree of organization of the communities (Shannon & Weaver 1963; Frontier 1985; Pielou 1977). Trophic groups were determined using Fauchald & Jumars (1979) and Rouse & Pleijel (2001).

Olmstead and Tukey's test (Sokal & Rohlf 1995) was applied to analyze spatial distribution of polychaetes. This technique plots the frequency of appearance in each site sampled expressed as percentage against the density of organisms for each species. A mean average was calculated for both axes, resulting in four quadrants: I Frequent and abundant species, II Non frequent and abundant species, III Non frequent and non abundant species and IV Frequent and non abundant species.

Stress predictability (Alcolado 1992) modeling was applied to establish the level of environmental stress existing in the bay. Environmental severity or stress was predicted based on values of diversity (H') and evenness (J'), coupled with redox potential values.

Ordination and classification methods were used to detect spatial patterns among the polychaete fauna. The relationship between sample stations is reflected by the position they display in factorial space; when the two stations were close to each other, they had more similar faunistic profiles (Frontier & Pichod-Viale 1993; Díaz-Castañeda et al. 1993). A factorial correspondence analysis was carried out on the faunistic data: abundance of species and 46 stations. Cluster analysis using Pearson and Bray-Curtis coefficients (Bray & Curtis 1957; Sokal & Rohlf 1995) was employed to evaluate the level of association of different stations and species. A non-metric multidimensional scaling (MDS) method was used for the community ordination (Program PRIMER 5.1.1 for windows) since this technique has demonstrated to be suitable for multiple ecological purposes (Clarke 1993; Clarke & Green 1988). The MDS is based on the calculation of similarity/dissimilarity coefficients among samples, in this case, the similarity coefficient of Bray-Curtis. One data matrix was created for each sampling period using abundance per species. Data were treated using Primer Program 5.1.1 for windows and Statistica v. 5.0, after transformation to $\log_{10}(X + 1)$ as suggested by Frontier (1983) and Legendre & Legendre (1984).

Results

In 1995, the redox potential values (Eh) were negative in most of the stations. In the eastern arm they varied between −340 and +162 mV; BF presented values between − 320 to +161 mV. Sediment temperatures oscillated between 19.1 and 22.0°C. Organic matter values varied between 0.3 to 3.4% in BSQ and 0.1 to 3.1% in BF. In 1998 only 43% of stations were measured for Eh and temperature.

Table 1. Physico-chemical values of San Quintín lagoon sediments.

	1995			1998		
Station	Eh(mV)	T°C	% O.M.	Eh(mV)	T°C	% O.M.
2			3.40			
3	−340	21.8	2.03	−336	20.2	4.05
4	155	21.6	1.68	−208	21.1	2.90
5	−106	20.2	2.84			
7	−160	20.9	1.86	−175	21.4	2.04
8	−196	20.8	1.38	−180	21.6	1.35
9	−245	20.8	2.01	−253	20.9	2.14
10	130	21.2	2.19			
11	−73	21.0	1.10			
12	−102	20.3	1.03	−98	20.8	1.66
13	−155	20.2	0.84			
14	−197	21.0	1.32	−144	21.2	1.48
16	−187	19.9	2.35			
17	−167	20.0	1.83			
18	−109	20.1	2.04	−120	21.4	2.40
19	−219	20.6	2.12			
21	−177		1.15	−174	21.5	1.57
22	−82	19.1	1.50	−92	21.4	1.92
24	162	21.7	2.46			
25	−112	21.1	1.27	−126	21.7	1.94
26	−95	21.6	0.80			
28	−62	20.5	1.38	103	21.5	1.45
29	66	21.1	0.91			
30	−43	21.3	0.30	154	19.8	0.50
31	−69	21.5	0.42			
32	−92	21.4	1.30			
33	161	21.7	0.22	187	21.3	0.55
34	−24	21.3	2.14			
35	−128	21.1	2.45			
36	−85	21.6	1.60	−106	21.8	1.66
38	−123	21.6	2.90	−152	21.8	1.87
39	−136	21.2	2.78			
40	−49					
41	33	21.3	2.90	−190	20.9	2.70
42	−176	21.5				
44	−320	21.2	3.27	−277	21.8	2.95
45				−308	22.1	4.11
46	−249	21.4	3.30			

In the eastern arm the Eh varied between −336 mV and +154, while the western arm presented values between − 308 and +187 mV. Sediment temperatures were in the range 19.8 to 22.1°C, while the organic matter content ranged between 0.5 to 4.0% in BSQ and 0.3 to 4.1% in BF (Table 1). These results show slightly lower Eh values and slightly higher temperature and organic matter contents in 1998.

The lists of species found in each survey are given in Table 2. In 1995, a total of 8,680 benthic organisms were collected, of which 38% were polychaetes, 36.5% were crustaceans and 27.4% were molluscs. The 3,275 polychaetes collected and identified belonged to 28 families, 56 genera and 104 species (Table 2).

The families best represented were Capitellidae (19%), Spionidae (17%), Sabellidae (14%), Lumbrinereidae (11%), Nereididae (9%), Cossuridae (8%) and Syllidae (8%). The 10 top dominant species were *Prionospio heterobranchia* (331), *Chone infundiliformis* (295), *Mediomastus californiensis* (264), *Cossura candida* (236), *Scoletoma crassidentata* (222), *Exogone lourei* (206), *Capitella capitata* (147), *Armandia brevis* (130), *Neanthes arenaceodentata* (121), *Chone mollis* (117). The first eight species constitute 55% of the total abundance, the first five have been reported as abundant in previous studies (Reish 1963; Calderón-Aguilera 1986; Díaz-Castañeda & Rodriguez-Villanueva 1998). Reish (1963) found six species that constituted the dominant bay species on the basis of number of specimens. These were, in decreasing order of importance, *Prionospio malmgreni, Exogone verugera, Cossura candida, Capitia ambiseta, Scoloplos acmeceps* and *Fabricia limnicola.* Calderón-Aguilera (1992) reported five numerically dominant species: *Exogone occidentalis, Pseudipolydora kempi, Scoloplos acmeceps, Prionospio heterobranchia* and *Neanthes arenaceodentata.*

In April 1998, a total of 5,584 benthic organisms were collected, of which 56.7% were polychaetes, 27.2% were crustaceans and 7.5% were molluscs. The 3,168 polychaetes identified, belonged to 21 families, 39 genera and 65 species (Table 2). The families best represented were Spionidae (47.6%), Capitellidae (12.3%), Syllidae (10.5%), Paraonidae (7%) and Orbiniidae (6.8%). The first six species constitute around 75% of the total abundance. The ten top dominant species were *Prionospio heterobranchia* (832 specimens), *Polydora websteri* (548), *Scoloplos acmeceps* (370), *Exogone lourei* (291), *Mediomastus californiensis* (273), *Cirriformia spirabrancha* (128), *Capitella capitata* (68), *Chone mollis* (62), *Megalomma pigmentum* (59) and *Fabricinuda limnicola* (50).

The following families present in 1995 were not found in the 1998 survey: Dorvilleidae, Polynoidae, Oweniidae, Scalibregmatidae, Sternapsidae and Sigalionidae. Some of these families have species that are carnivorous. The increase in temperature in 1998 is related to a diminution of prey items which in turn may have affected their abundances.

Olmstead & Tukey's graph is only presented at the family level (Fig. 2a), because there were too many species to produce a clear graph. In 1995 and 1998 the polychaete families were placed in three out of four possible categories: dominant, restricted and rare. In 1995, in quadrant I (frequent and abundant), 6 polychaete families were characterized as dominant. Spionidae, Nereididae, Sabellidae, Lumbrinereidae, Capitellidae and Syllidae families displayed high densities and wide distribution throughout the lagoon. The families Spionidae, Capitellidae, and Sabellidae presented the highest densities and combined accounted for 45% of the total abundance of polychaetes. Ten families restricted to certain areas of the lagoon were located in quadrant II (non-frequent and abundant) and corresponded to 32% of all families. Within quadrant III (non-frequent and non-abundant), 12 polychaete families were located, classified as rare or occasional. No families were located in quadrant IV corresponding to frequent and non-abundant families. Approximately 35% of species were located in quadrant I (36 species). In 1998 (Fig. 2b), in quadrant I, only 3 polychaete families were characterized as dominant. The families Spionidae, Orbiniidae and Capitellidae displayed high densities and

Table 2. Polychaete species from San Quintín lagoon, Baja California.

Species	1995	1998
AMPHARETIDAE		
Ampharete labrops Harman, 1961	x	
Ampharete sp	x	
Amphicteis acutifrons Grube, 1850		x
Amphicteis sp Grube, 1850		x
CAPITELLIDAE		
Capitella capitata Fabricius, 1780	x	x
Mediomastus californiensis Hartman, 1944	x	x
Mediomastus sp	x	x
Notomastus magnus Hartman, 1947		x
Notomastus tenuis Moore, 1909	x	x
Notomastus sp		x
CIRRATULIDAE		
Aphelochaeta marioni Saint-Joseph, 1894	x	
Aphelochaeta sp	x	
Cirriformia spirabranchia Moore, 1904	x	x
Monticellina tesselata Harman, 1960	x	
Protocirrineris socialis Blake, 1996	x	
Protocirrineris sp		x
COSSURIDAE		
Cossura candida Hartman, 1955	x	x
Cossura sp A	x	x
DORVILLEIDAE		
Dorvillea sp	x	
EUNICIDAE		
Lysidice ninetta Verril, 1900	x	
Marphysa disjuncta Harman, 1961	x	
M. sanguínea Montagu, 1815	x	x
Marphysa sp	x	x
FLABELLIGERIDAE		
Pherusa capulata Moore, 1909	x	x
Piromis arenosus Kinberg, 1867	x	x
Piromis sp		x
GLYCERIDAE		
Glycera americana Leidy, 1855	x	x
G. tenuis Hartman, 1944	x	x
GONIADIDAE		
Goniada brunnea Treadwell, 1906	x	
G. littorea Hartman, 1950	x	x
HESIONIDAE		
Podarkeopsis glabra Hartman, 1961	x	x
Podarke pugettenisis Johnson, 1901	x	x
LUMBRINERIDAE		
Scoletoma crassidentata Fauchald, 1970	x	
S. erecta Moore, 1904	x	
S. monroi Fauchald, 1970	x	
S. tetraura Schmarda, 1860	x	x

Table 2. Continued.

Species	1995	1998
MALDANIDAE		
Axiothella rubrocincta Johnson, 1901	x	
Axiothella sp Verril, 1900	x	
Clymenura gracilis Moore, 1923		x
Euclymeninae sp A Ardwidsson, 1906		x
Isocirrus longiceps Moore, 1923	x	
Maldane sp	x	
NEPHTYIDAE		
Nephtys caecoides Hartman, 1938	x	x
Nephtys sp		x
NEREIDIDAE		
Neanthes caudata delle Chiaje, 1828	x	x
Nereis latescens Chamberlin, 1919	x	
N. pelagica Linné, 1758	x	
Nereis sp		x
Platynereis bicanaliculata Baird, 1863	x	
P. marphysa		x
OENONIDAE		
Arabella iricolor Montagu, 1804	x	x
A. pectinata Fauchald, 1970	x	
Drilonereis falcata Moore, 1911	x	
D. longa Webster, 1879	x	
D. mexicana Fauchald, 1970		x
Drilonereis sp		x
Notocirrus californiensis Hartman, 1944		x
ONUPHIDAE		
Kinbergonuphis sp	x	x
OPHELIIDAE		
Armandia bioculata Hartman, 1938	x	
A. brevis Moore, 1906	x	x
Ophelia pulchela Tebble, 1953		x
Polyophthalmus picuts Dujardin, 1839	x	
ORBINIDAE		
Leitoscoloplos mexicanus Fauchald, 1972	x	
L. normalis Day, 1977	x	
Naineris grubei Gravier, 1908		x
Phylo felix Kinberg, 1866	x	
P. ornatus Verril, 1873	x	
Scoloplos acmeceps Chamberlain, 1919	x	x
S. armiger Müller, 1776	x	
S. ohlini Ehlers, 1901		x
S. texana Maciolek & Holland, 1978		x
OWENIIDAE		
Owenia collaris Hartman, 1955	x	
PHYLLODOCIDAE		
Eteone pacifica Hartman, 1936	x	
Eteone sp	x	x
Eulalia bilineata Johnston, 1840	x	
Eumida sp		x

Table 2. Continued.

Species	1995	1998
POLYNOIDAE		
Harmothoe imbricata Linné, 1767	x	
Harmothoe sp		x
SABELLIDAE		
Chone infundibuliformis Kröyer, 1856	x	
C. mollis Bush, 1904	x	x
Fabricinuda limnicola Hartman, 1951	x	x
Megalomma pigmentum Reish, 1963	x	x
SCALIBREGMATIDAE		
Scalibregma sp	x	
SIGALIONIDAE		
Sthenelais fusca Johnson, 1897	x	
SPIONIDAE		
Aporionospio pigmaeus Hartman, 1961	x	
Boccardiella hamata Webster, 1879	x	x
Microspio pigmentata Reish, 1959		x
Minuspio cirrifera Wirén, 1883	x	
Polydora socialis Schmarda, 1861		x
P. websteri Hartman, 1943		x
Prionospio heterobranchia Reish, 1959	x	x
P. lighti Maciolek, 1985	x	x
Pseudopolydora pauchibranchiata Okuda, 1937	x	
Scolelepis squamata Müller, 1806	x	
Spiophanes bombyx Claparéde, 1870	x	
S. duplex Chamberlain, 1919	x	x
S. missionensis Hartman, 1941	x	
Spio pacifica Blake & Kudenov, 1978	x	
Spio sp		x
SYLLYDAE		
Cicese sphaerosylliformis Díaz & San Martín, 2001	x	x
Eusyllis sp	x	
Exogone lourei Berkeley & Berkeley, 1938	x	x
Grubeosyllis mediodentata Westheide, 1974	x	x
Pionosyllis sp	x	x
Sphaerosyllis californiensis Hartman, 1966		x
Syllis aciculata Treadwell, 1945	x	
S. gracillis Grube, 1840	x	x
S. heterochaeta Moore, 1909	x	
Syllis sp		x
TEREBELLIDAE		
Eupolymnia nebulosa Montagu, 1818	x	
Pista alata Moore, 1909	x	x
Pista sp	x	x
Polycirrus sp		x

Table 3. Polychaete species recorded in previous studies at San Quintín lagoon, Baja California. Numbers correspond to the different taxa recorded in the area.

Reish, 1963	
1	*Anaitides ca. multiseriata*
2	*Anaitides williamsi*
3	*Arabella iricolor*
4	*Arenicola cristata*
5	*Armandia bioculata*
6	*Axiothella rubrocincta*
7	*Brania clavata*
8	*Capitella capitata*
9	*Capitita ambiseta*
10	*Chone mollis*
11	*Chrysopetalum occidentale*
12	*Cirrifornia luxuriosa*
13	*Cirrifornia spirabrancha*
14	*Cossura candida*
15	*Dorvillea articulata*
16	*Eteone dilatae*
17	*Eteone pacifica*
18	*Eulalia bilineata*
19	*Exogone verugera*
20	*Fabricia limnicola*
21	*Glycera americana*
22	*Goniada brunnea*
23	*Hapioscoloplos elongatus*
24	*Lepidonotus caelorus*
25	*Lumbrineris erecta*
26	*Lumbrineris minima*
27	*Marphysa sanguinea*
28	*Megalomma pigmentum*
29	*Nephtys caecoides*
30	*Nereis caudata*
31	*Nerinidaes maculata*
32	*Notomastus magnus*
33	*Onuphis microcephala*
34	*Ophiodromus puggettensis*
35	*Pista alata*
36	*Platynereis bicanaliculata*
37	*Polydora uncata*
38	*Polyophthalmus pictus*
39	*Prionosopio malmgreni*
40	*Prionospio pygmaeus*
41	*Scoloplos (L) ohlini*
42	*Scoloplos acmeceps*
43	*Scyphoproctus oculatus*
44	*Sphaerodorum minutum*
45	*Spiophanes missionensis*
46	*Trypanosyllis gemmipara*
47	*Typosyllis variegata*
48	*Aedicira pacifica*
49	*Aricidea suecica*
	Armandia bioculata
	Axiothella rubrocincta
	Brania clavata
	Chone mollis
	Cirrifornia luxuriosa

Table 3. Continued.

50	*Cossura soyeri*
	Eteone dilatae
	Eteone pacifica
	Exogone occidentalis
	Fabricia limnicola
	Kinbergonuphis microcephala
	Leitoscoloplos pugettensis
	Lepidonotus squamatus
	Lumbrineris erecta
	Lumbrineris mimima
51	*Magelona pitelkai*
	Marphisa sanguinea
52	*Mediomastus ambisetus*
53	*Mediomastus californiensis*
	Megalomma pigmentum
	Neanthes arenaceodentata
54	*Nephtys caecoides*
55	*Nephtys ferruginea*
	Notomastus magnus
	Notomastus tenuis
	Pherusa capulata
56	*Phylo felix*
	Pista alata
	Platynereis bicanaliculata
	Polyophtalmus pictus
57	*Prionospio cirrifera*
58	*Prionspio heterobranchia*
59	*Prionospio malmgreni*
60	*Prionospio newportensis*
61	*Pseudopolydora kempi*
	Scolelepis maculata
	Scolopios acmeceps
	Scyphoproctus oculatus
	Spiophanes missionensis
62	*Apistobranchus sp*
	Arabella iricolor
63	*Brada villosa*
	Brania sp.
64	Cirrifornia cf. spirabrancha
	Chaetozone sp.
	Chone sp.
65	*Clymenura gracilsis*
	Cossura candida
66	*Euchone sp.*
67	*Exogone dispar*
68	*Exogone lourei*
69	*Goniada maculata*
	Kinbergonuphis cf microcephala
70	*Leitoscoloplos mexicanus*
71	*Lysidice ninetta*
72	*Marphysa sanguinea*
	Megalomma bioculatum
73	*Monticellina tesselata*
	Neanthes acuminata
	Nereis sp.
	Notomastus sp.

Table 3. Continued.

74	*Pionosyllia sp.*
75	*Polydora socialis*
76	*Praxillela sp.*
77	*Prionospio multibranchiata*
	Prionospio (Minuspio) cirrifera
	Prionospio heterobranchia
78	*Scoletoma tetraura*
79	*Scoloplos rubra*
80	*Spio pettiboneae*
81	*Syllis (Syllis) gracilis*

when combined accounted for 70% of the total abundance. Seven families restricted to certain areas of the estuary were located in quadrant II (non-frequent and abundant) and corresponded to 33% of all families. Within quadrant III (non-frequent and non-abundant), 11 polychaete families were located, and corresponded to rare or occasional. No families were located in quadrant IV. 25% of species were located in quadrant I (16 species).

BSQ exhibited a broad range of species richness per station. Values varied between 6–13 species in heads of both estuary arms and 3–26 species in the middle sections of both basins (Fig. 3).

Higher abundance values, more than 100 polychaetes/station were located largely on the southern half of BSQ, only one of these stations was located in the northern part of BF (station 46). In both surveys, SQB presented higher polychaete densities and diversity values, probably the oyster aquaculture in BF although not intensive has produced a certain impact in the benthic communities due to an excess of organic matter.

In 1995, in BSQ several stations presented diversity values higher than 3.50, station 14 had 4.15; three stations (5, 9, 20) reached 25 species. On the contrary, in BF only one station (14) presented a higher value than 3.50 (station 41), seven stations presented diversity values between 3.00 and 3.50, no stations had values higher than 4.00. No station reached an specific richness of 25, the highest value was 19 species in station 22.

From the 30 families already reported by Reish (1959), Calderón-Aguilera (1992), Díaz-Castañeda & Rodríguez-Villanueva (1998), 23 have been found in the present work and six families are added: Ampharetidae, Oweniidae, Scalibregmatidae, Sternapsidae, Dorvilleidae and Sigalionidae. The seven families not found in 1995 and 1998 were: Paraonidae, Magelonidae, Apistobranchidae, Sphaerodoridae, Trichobranchidae, Chrysopetalidae and Arenicolidae.

From the 6,443 polychaetous annelids collected in both cruises, representing 104 species, 53% (55 species) correspond to new records for the area. Thirty species were common to both sampling campaigns. One new genus and a new species was found in the eastern arm, in stations 8, 17 and 23 of BSQ: *Cicese sphaerosylliformis,* reported separately (Díaz-Castañeda & San Martin 2001). From the 104 polychaete species found in 1995, 41% (43 species) are recorded for the first time, whereas from the 65 species collected in 1998, 33% (22 species) correspond to new records. Species richness and diversity were higher in BSQ

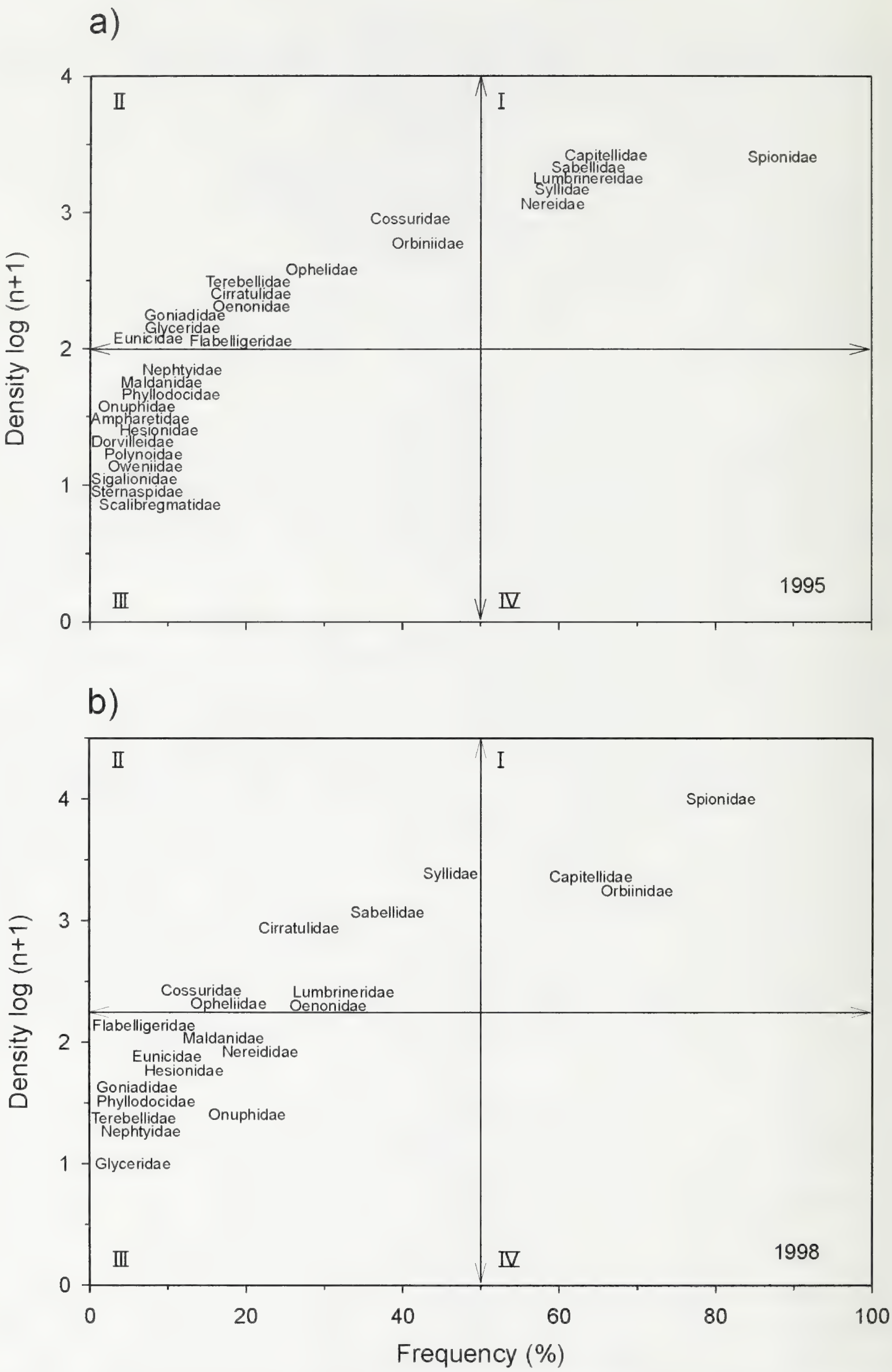

Fig. 2. Relationship between frequency (%) and density (org. 0.1 m^2) of polychaete families using Olmstead and Tukey's technique: a) 1995 B) 1998.

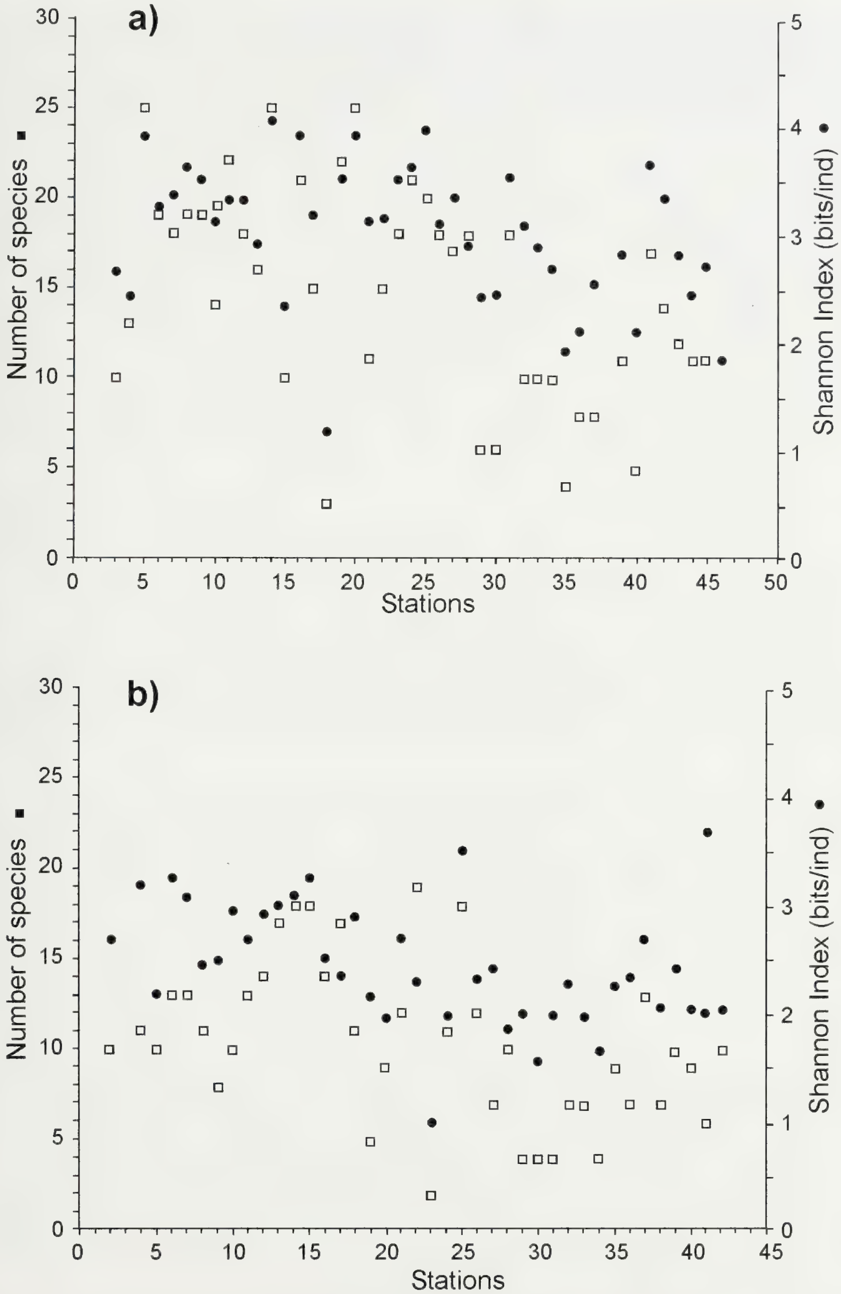

Fig. 3. Diversity (H′) and species richness of polychaetes collected in both surveys: a) 1995, b) 1998.

(Fig. 3), 11 stations in BSQ had diversity values higher than 3.5, only station 40 located in the northern section of BF presented a diversity value higher than 3.5.

Although abundances were similar in 1995 and 1998, we noted a change in the composition and structure of the polychaete communities; species richness diminished signficantly from 104 to only 65, reflecting the diminution of diversity values and equitability of the communities. The trophic structure also changed as deposit-feeders increased their numbers, and the abundance of other trophic categories diminished, indicating a modification in community organization and loss of complexity.

Significant variations in the abundance of some important families were detected between 1995 and 1998; some increased their abundances: Spionidae from 17% to 48%, Orbiniidae from 4% to 13%. These families are essentially deposit-feeders although some species of spionids can also feed as filter-feeders. Other families decreased in terms of number of species: Lumbrinereidae from 11% (4 species) to 1.4% (1 species), Nereididae from 9% (5 species) to 1% (only 2 species) and Sabellidae from 14% to 5% (3 species). Lumbrinereids live in sand or mud, in plant roots or in algal hold-fasts, nereidids are omnivores and herbivores and sabellids are filter-feeders. These modifications changed the diversity and structure of polychaete communities in this lagoon.

Diversity values ranged between 1.18–4.04 in 1995, and 1.10–3.51 in 1998, with higher values mainly located in BSQ, especially the middle section (Fig. 3). Diversity in BF diminished in 1998, reaching a maximum of 2.71. In 1995, 55% of stations presented equitability (Pielou index) values higher than 0.800, indicating a more or less even distribution of polychaetes at the species level. Whereas in 1998 only 35% of stations reached more than 0.800. BF presented in both surveys lower equitability and diversity values, probably this is related to the increasing oyster culture which seem to affect the benthos due to negative Eh values.

Values of species diversity (H′) and evenness (J′) for stations sampled were analyzed and placed into four "environments" (Fig. 4) as defined by the Stress-Predictability modeling (Alcolado 1992). We found seven times more stations classified in environment I (very favorable and stable) in 1995 compared to 1998.

In 1995 (Fig. 4a), environment I, which included 21 stations with the highest values of diversity (H′) (2.52–4.04) and evenness (J′) (0.740–0.910), was characterized as being very favorable and stable. Environment II was represented by 11 stations (10, 13, 21, 24, 26, 28, 32, 33, 34, 38, 42) located in the middle areas of BSQ and BF, it was favorable and stable, H′ values ranged between 2.68–3.62 and J′ values between 0.694–0.910. Environment III (stations 2, 3, 4, 15, 37, H′ 2.41–2.89, J′ 0.653–0.849) was characterized as being constant, with a degree of environmental stress. Finally, environment IV which corresponded to stations 18, 35, 36 and 39, was moderately favorable, with unstable conditions and a certain degree of environmental stress. Environment IV station diversity values (H″) oscillated between 1.17–2.83, evenness values (J″) from 0.700 to 0.960, and were the lowest of this study.

Whereas in 1998 (Fig. 4b), environment I included only 3 stations (6, 15, 25) with the highest values of diversity (H′) (3.24–3.52) and evenness (J′) (0.777–0.878), was characterized as being very favorable and stable. Environment II was constituted by 10 stations (2, 3, 4, 10, 11, 12, 13, 14, 18, 21) situated mainly in the medium section of BSQ, it was favorable and stable, H′ values ranged between 2.42–3.18 and J′ values between 0.723–0.918. Environment III increased with respect to 1995 survey, it was formed by 12 stations located in both arms (5, 8, 9, 16, 19, 26, 27, 32, 35, 36, 39, 43), H′ 2.16–2.51, J′ 0.575–0.836) characterized

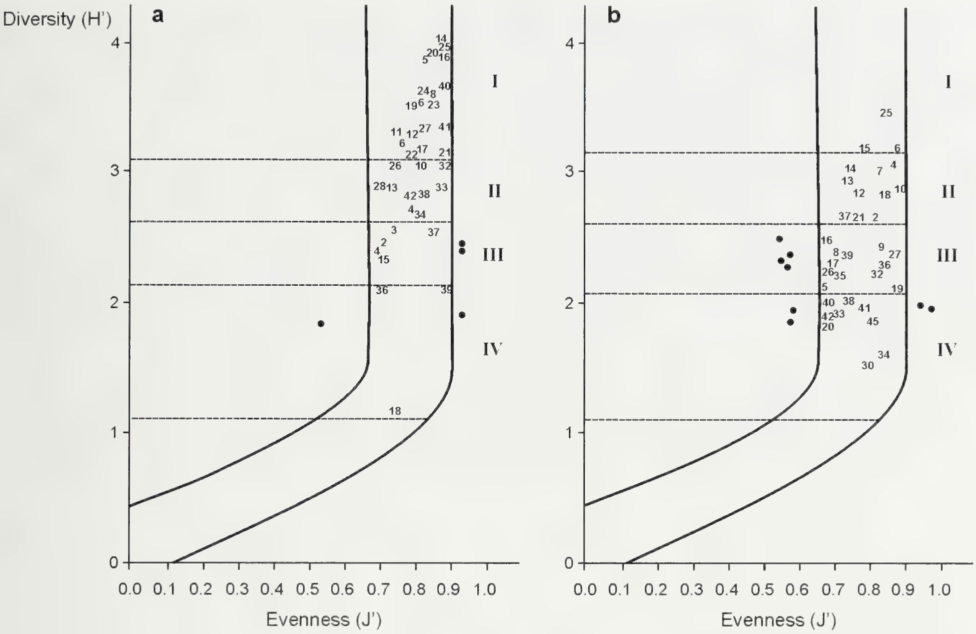

Fig. 4. Stress-Predictability modeling (Alcolado 1992). Stations are located in different environments: I Very favorable and stable, II favorable and stable, III constant with a degree of environmental stress, IV moderately favorable, unstable conditions and a certain degree of environmental stress.

as being constant, with a degree of environmental stress. Finally, environment IV which corresponded to stations 30, 33, 34, 38, 40, 41, 42 and 45, located in the middle of BF was moderately favorable, with unstable conditions and a certain degree of environmental stress. Environment IV station diversity values (H″) oscillated between 1.56–2.16, evenness values (J″) from 0.640 to 0.831, and were some of the lowest of this study. The number of stations in this last category almost doubled in relation to 1995.

In relation to trophic groups, polychaete species found in 1995 and 1998 were in decreasing order of importance: deposit-feeders, carnivores, filter-feeders and herbivores. Deposit-feeders increased their numbers in 1998. We also detected an important presence of carnivores, essentally syllids, which increased their abundance in 1998. Spionidae and Capitellidae which were among the most abundant families have species which are surface and subsurface deposit-feeders, as well as filter-feeders. The dominant species *Prionospio heterobranchia* can feed as a deposit-feeder or as a filter feeder, this capacity allows them to stay and even increase their abundances in disturbed conditions.

The families best represented in 1995, by decreasing order of importance were Capitellidae, Spionidae, Sabellidae, Lumbrinereidae and Nereididae, they changed in 1998: Spionidae, Orbiinidae, Capitellidae, Syllidae, Sabellidae.

Bray-Curtis coefficient of similarity was used to measure the level of association of samples. The dendrogram (Fig. 5a) generated with samples and replicates from 1995 revealed a clear separation between both arms, to the right of the graph are located BSQ samples and to the left BF samples (except stations 4 and 15). BF revealed four groups at 30% level of similarity: group I with 6 stations from

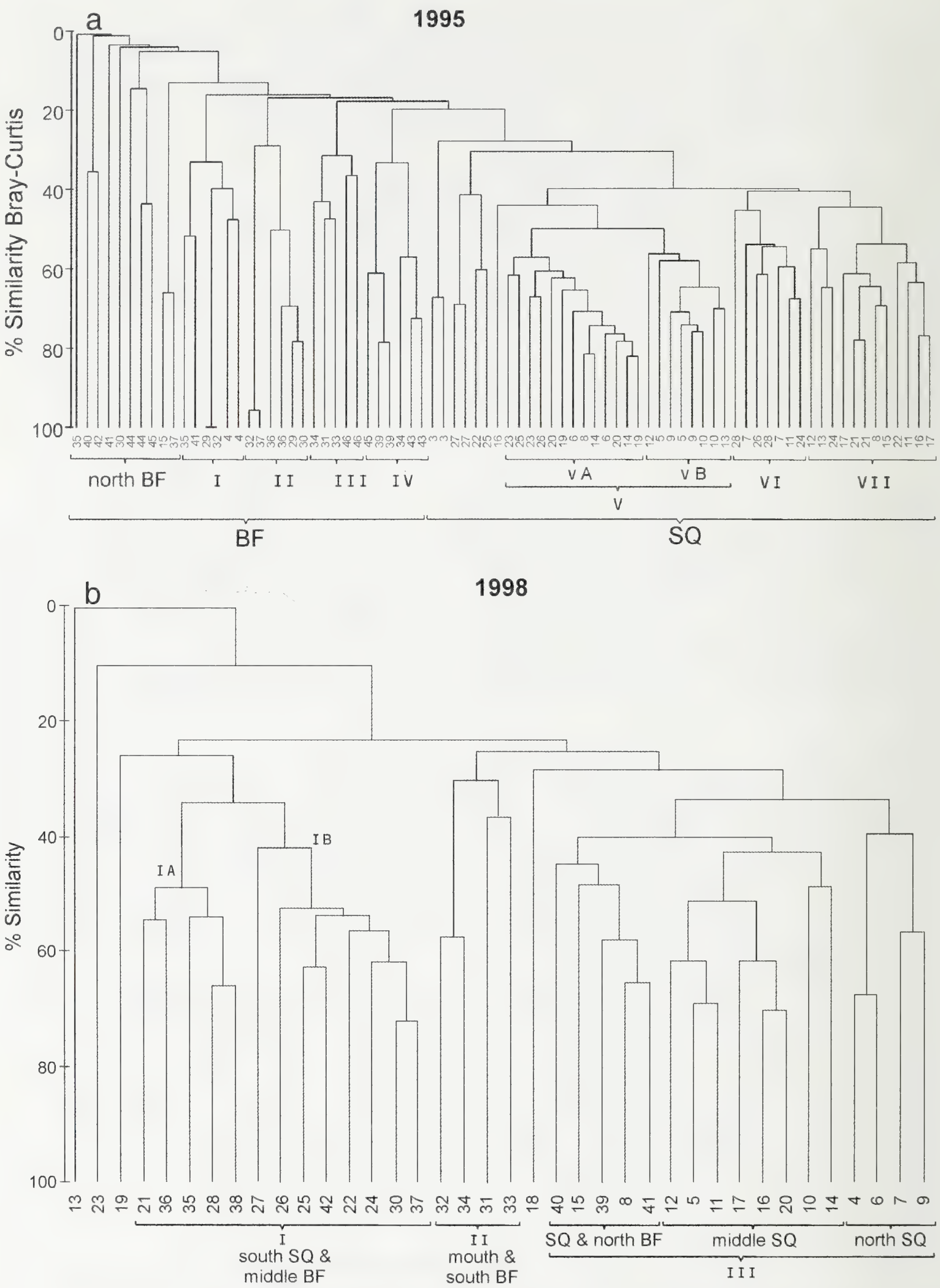

Fig. 5. Bray-Curtis dendrogram showing classification of stations sampled in 1995 (a) and 1998 (b).

the middle and mouth, group II formed by six stations from the southern section and mouth, group III constituted by five stations from the north and near the mouth and group IV formed by 6 stations from the western section. Groups III and IV are formed by stations from the northern section which is the least well flushed. At the left of the figure appear 9 stations connected to the other groups with low levels of similarity. At 42% similarity SQB samples are separated into three groupings: group V comprised 21 stations, it is subdivided in two groups, VA constituted by 13 stations located in the middle and south and VB formed by eight stations from the north, group VI gathered seven stations from the middle and south and group VII is constituted by 12 stations from the middle section of the bay.

The dendrogram (Fig. 5b) generated with samples from 1998 revealed also a separation between both arms, although it is less clear than in 1995. To the right of the graph are located mainly SQB samples and to the left most of BF samples. At 30% level of similarity which correspond to a faunistic dissimilarity for the bay we observe 3 groups: group I formed by 13 stations from middle SQB and east BF, at a higher level of similarity it is subdivided in two groupings IA formed by stations from middle BF and south BSQ and IB which gather stations from the southern half of BSQ. Group II formed by four stations located near the mouth and group III constituted by 18 stations subdivided in three groupings which represent respectively north BF and middle BSQ, middle BSQ and north BSQ.

Factorial Correspondence Analysis (FCA) and non metric MDS were applied to a matrix of 104 species and 45 stations in 1995, and a matrix of 65 species and 42 stations in 1998. Data treated correspond to the polychaete species abundances. Some representative graphics were selected.

In 1995, the first two axis extracted 45.5% of total inertia. In the factorial plane 1–2 we observed that samples from each lagoon arm gathered, forming BF and BSQ two separate groups in the factorial space (Fig. 6a). Most of the stations of BSQ were located on the positive side of axis 2 whereas all stations of BF were situated in the negative side of this axis which indicate that polychaete communities inhabiting each lagoon arm are not exactly the same, even if the species list is similar, the proportion between species change. This can be explained by the fact that hydrological conditions are not the same in both arms, depth averages are 4 and 8 m in BF and BSQ respectively. Conditions in BF can favor the development of more sensible species, those that can not tolerate very low oxygen concentrations and/or very negative Eh values because in this arm the water exchange with the sea is faster (Díaz-Castañeda & Rodriguez-Villanueva 1998). However if oyster aquaculture increases, it may cause a negative effect in the water and sediment quality, affecting these species.

In 1998, the first two axes extracted 55.2% of total inertia. In the factorial plane 1–2 (Fig. 6b), BF stations appear together, forming two groups. One of the groups is located on the positive side of axis 2, the second group which correspond to the southern section is situated on the negative side of this axis, near the stations from north BSQ. BSQ stations form a group that extends along axis 1, the stations from the north (negative side of axis 2), middle and southern sections differentiate.

Polychaete communities were also examined using non metric multidimensional scaling. This analysis also provided evidence of a separation between samples of the eastern and western arms of the bay. MDS analysis applied to data from

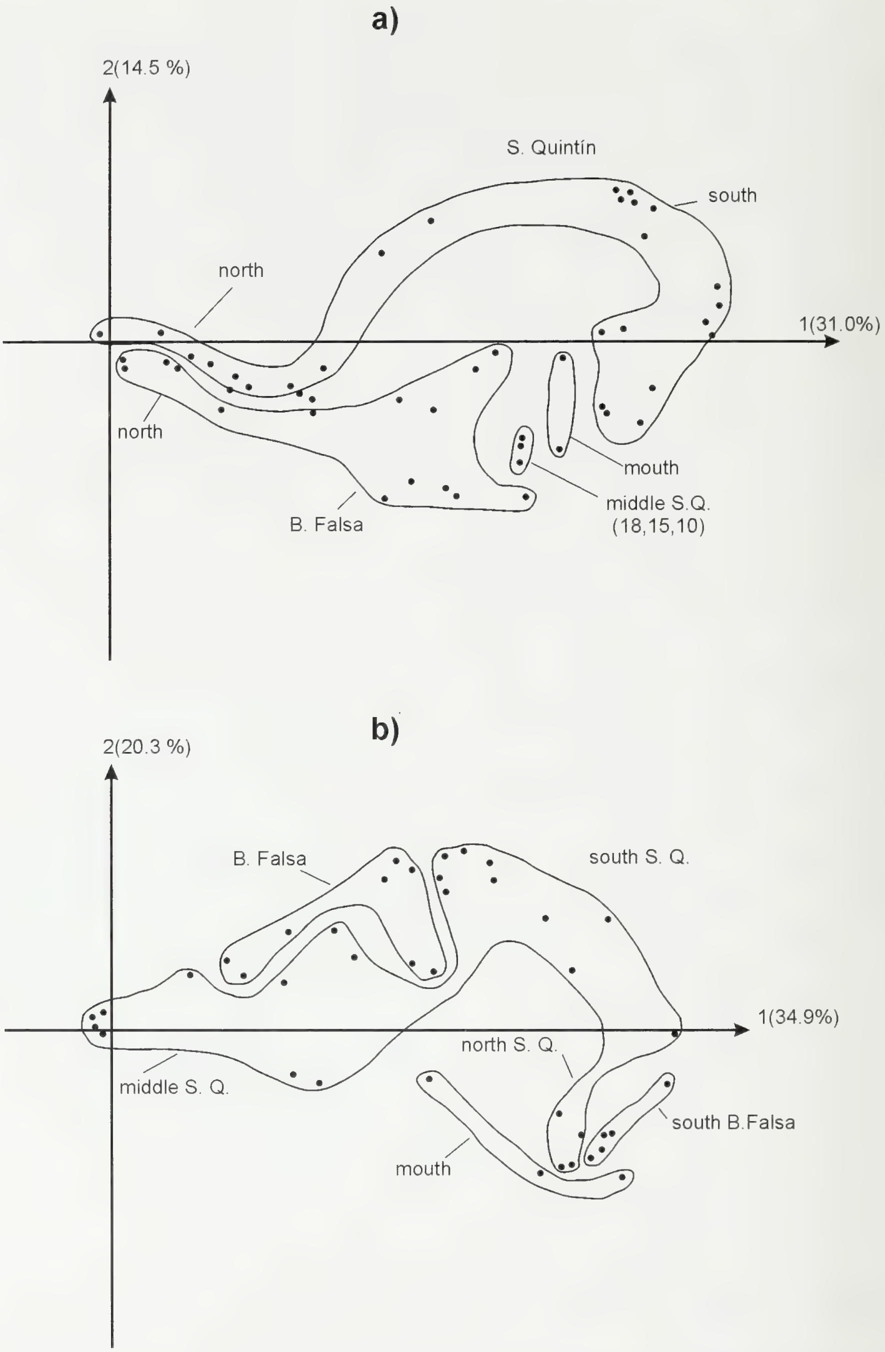

Fig. 6. Factorial Correspondance Analysis (FAC) ordination of sampled stations in Bahía San Quintín.

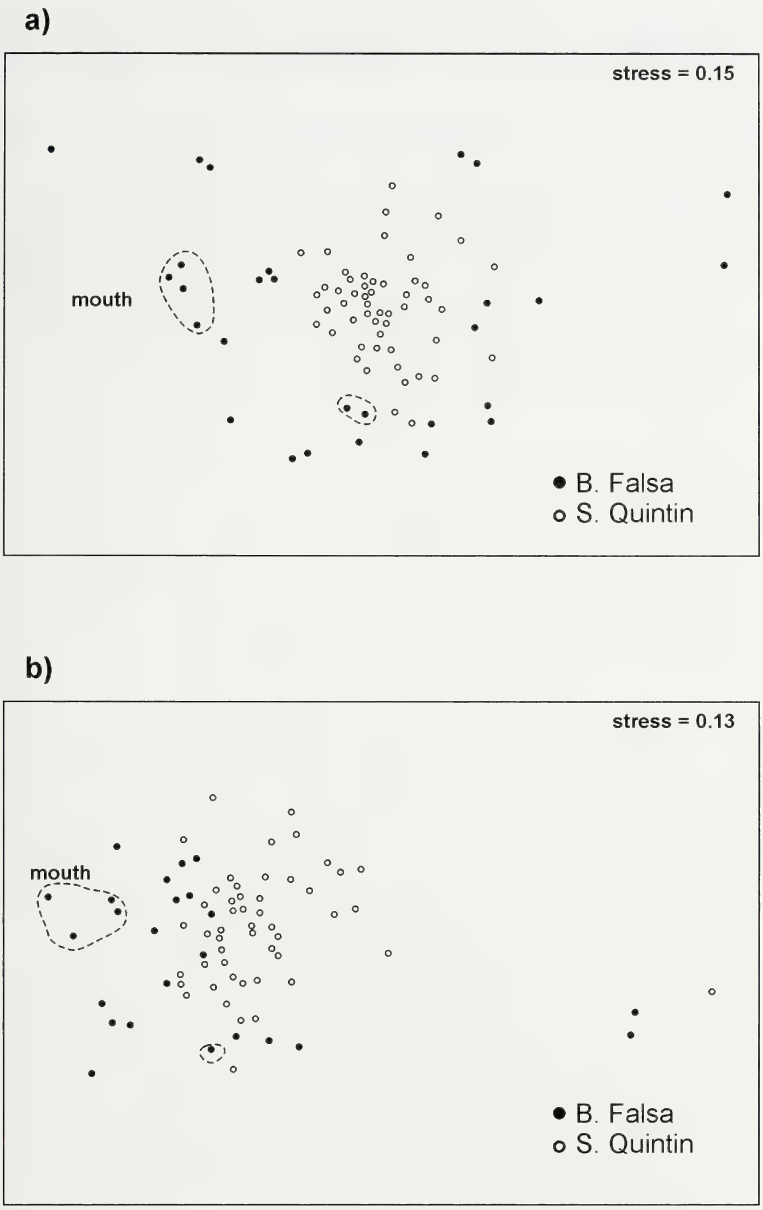

Fig. 7. Non-metric multidimensional scaling (MDS) ordination of stations sampled in 1995 (a) and 1998 (b).

1995 (Fig. 7a) revealed a group of stations located in the center which correspond to BSQ; to the right are located stations from the northern area. Around these stations are located those from BF. The stations near the mouth are surrounded by a dotted circle. Stress value (0.15) indicated that the configuration was a good representation of the faunistic similarities between stations. In 1998 (Fig. 7b) the separation between stations from BSQ and BF is also observed but not so clearly, stations from north BSQ are situated in the right and upper section. Most BSQ stations are located in the right side, while BF are mainly in the left. Stress value is 0.13. The mouth stations are essentially located in the same position than in 1995.

In conclusion, the study of polychaete communities in both arms of San Quintin lagoon showed in both surveys differences in species diversity, composition of species and abundances. Polychaete communities seemed to have balanced according to the physico-chemical characteristics prevailing in the area in 1995 and 1998. The proportion of families changed, some families disappeared completely in the 1998 survey: Dorvilleidae, Polynoidae, Oweniidae, Scalibregmatidae, Sternapsidae, Sigalionidae. Seven families found in 1992 (Díaz-Castañeda & Rodríguez-Villanueva 1998) were not collected in 1995 or 1998: Paraonidae, Magelonidae, Apistobranchidae, Sphaerodoridae, Trichobranchidae, Chrysopetalidae and Arenicolidae.

The eastern arm (SQB) presented in both surveys, higher polychaete densities and diversity values, probably the oyster aquaculture in Falsa Bay although not intensive has produced a certain impact in the benthic communities due to an excess of organic matter, resulting in negative Eh values and reduction of abundance and diversity. Comparing the polychaete composition and the values of some ecological indexes (Shannon Index, Pielou, Simpson dominance) between 1995 and 1998 we detected an important diminution of the species richness and diversity.

In BSQ several stations presented diversity values higher than 3.50, one station had more than 4.0; in BF only one station presented a higher value than 3.50, no stations had values higher than 4.0. Higher species richness values were located in BSQ (up to 26/station), indicating that this is an adequate environment for polychaetes development. It seems that the physico-chemical characteristics prevailing in each arm, as well as water exchange rates influence benthic communities development. The mathematical methods applied allowed a better global vision of the organization and structure of these populations.

Increased environmental variability due to the ENSO 97–98 probably may have affected recruitment, survival and reproductive patterns of polychaete species, modifying the composition and structure of polychaete communities between 1995 and 1998. In Chile, Escribano et al. (2004) found increased benthic bioturbation during the same period. Probably there was seagrass reduction (*Zostera marina*) in 1998 that could have indirectly affected zoobenthic recruitment, which is partially driven by the hydrodynamic environment modified by seagrass meadows, as has been observed by other authors (Bostrom & Bonsdorff 2000).

Finally, in San Quintin lagoon more than 50% of stations had relatively high values of diversity and evenness, indicative of healthy benthic communities. In general, the bay is characterized by high diversity values and approximately 70% of stations were favorable and constant environments for polychaetes, especially in the southern area of BF where the bivalve culture takes place and the middle section of BSQ.

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Composition of the Epifaunal Community Associated with the Seagrass *Zostera marina* in San Quintin Bay, Baja California

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Abstract.—The epifaunal community associated with eelgrass beds in San Quintin Bay, Baja California, Mexico, was studied from April to November 1993. Taxonomic identification, univariate community descriptors, and biomass data were obtained for each sample. Multivariate analyses of community composition were also performed, and plant–animal relationships were analyzed. The epifaunal community was characterized by the high abundance of a few dominant species, with the mollusk *Assiminea dubiosa* representing 70% of the total abundance. Summer samples had the highest similarity, as indicated by the Analysis of Similarity (ANOSIM) test. Polychaetes and amphipod abundances seemed to follow the variations in eelgrass aboveground biomass.

Seagrasses are aquatic angiosperms with a high degree of uniformity in their vegetative appearance. Almost all genera have well-developed subterranean rhizomes and strap-shaped leaves. There is however, a considerable degree of diversity in the mode of growth, the branching system, and in the anatomical structure (Den Hartog 1967). Seagrasses grow in suitable shallow marine waters worldwide, and are represented by 7 tropical and 5 temperate genera (Den Hartog 1970). Although present across only 0.15% of the ocean surface, they account for about 1% of the net primary production and 12% of the net ecosystem production of the global ocean (Duarte and Cebrián 1996).

Seagrasses are among the most productive autotrophic communities on the planet (Hillman et al. 1989; Duarte and Chiscano 1999). Their high biomass and production is directly linked with their important role in the ecosystem. For this reason, seagrasses have been considered among the most valuable ecosystems in the world in terms of the value-added services they provide (Costanza et al. 1997).

Ecological functions associated with seagrasses include nutrient recycling, detritus production and export, sediment stabilization, and provision of optimal habitat for growth, survival and reproduction of a diverse array of vertebrate and invertebrate taxa (Heck et al. 1997, 2003). Further, biodiversity generally appears to be higher in seagrass relative to adjacent habitats (Orth et al. 1984; Bell and

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Pollard 1989; Orth 1992), although the magnitude of this difference depends on seagrass species composition and biomass (Heck et al. 2003). For this reason, seagrasses are viewed as extraordinarily rich habitats (Kikuchi 1980; Heck et al. 2003).

Recent theories on mechanisms controlling energy flow in seagrass beds emphasize the importance of intermediate trophic levels, with large invertebrates acting as effective predators on the smaller invertebrate fauna (Klumpp et al. 1989) and small invertebrate grazers controlling epiphytic algal abundance (van Montfrans et al. 1982; Hootsman and Vermaat 1985). Experimental research has shown important top-down effects in determining the composition and abundance of seagrass-associated plants and animals in natural conditions, thus supporting the hypothesis that small grazers can often control the abundance of epiphytes, and emphasizing the need to know how grazer populations are regulated in order to fully understand the consequences of human perturbations (e.g. nutrient enrichment) on seagrass ecosystems (Heck et al. 2000).

With this functional perspective in mind, and recognizing the urgent need to have detailed information on the composition of the mobile fauna in San Quintin Bay, we collected data on the epifaunal and mobile species assemblages. We here present the epifauna data, for which we first characterized the species composition, performed univariate community analysis, and calculated biomass. We then performed multivariate analysis of community composition, and analyzed plant–animal relationships using correlation analysis. Our data on species composition, changes in community composition over time, and plant–animal relationships were compared with those reported for other locations, and other seagrass species.

Materials and Methods

Study Site

San Quintin Bay is a Y-Shaped coastal lagoon located on the Pacific coast of Baja California. The east arm is known as Bahia San Quintin, and the west arm as Bahia Falsa (Fig. 1). The bay covers an area of about 42 km^2 and has a mean depth of about 2 m. Tides are semidiurnal with a mean amplitude of 1.6 m (C. Nava, Sea Level Laboratory, CICESE, personal communication). Water exchange with the coastal ocean is intense, with about 11 days water residence time for San Quintin Bay, and 4 days for Bahia Falsa (Camacho-Ibar et al. 2003). Water temperature ranges from 13 to 27°C inside the bay and from 11 to 22°C at the mouth (Alvarez-Borrego and Alvarez-Borrego 1982).

Total evaporation in summer (164×10^3 m^3 day^{-1}) and winter (91×10^3 m^3 day^{-1}) exceed total rainfall (4×10^3 m^3 day^{-1}), and there is ordinarily no significant runoff or groundwater inflow. Consequently, San Quintin Bay is a net evaporative system (Ibarra-Obando et al. 2001), with summer and winter salinities in the interior (38.7–33.8‰) always higher than in the adjacent ocean (33.8–33.6‰) (Millán-Núñez et al. 1982).

San Quintin Bay is characterized by extensive eelgrass (*Zostera marina*) beds, best developed in the middle bay on soft sediment bottom plains that are covered with between 0.3 m and 0.9 m of water at the lowest tide. Present eelgrass coverage is about 40% (Ward et al. 2003). The benthic invertebrates of vegetated and unvegetated areas have been studied, both at the taxon level (Keen 1962;

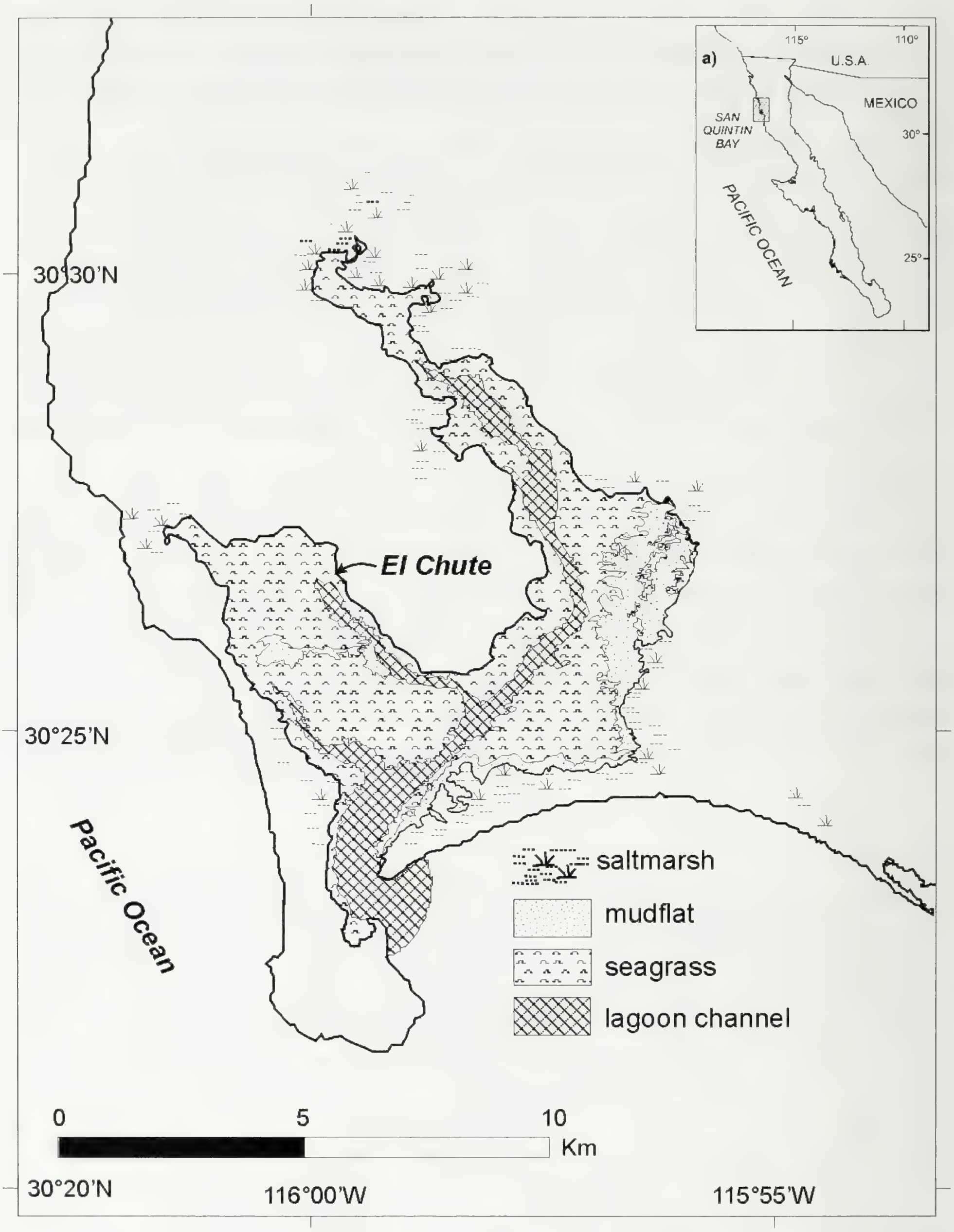
a)
115°
110°
U.S.A.
MEXICO
SAN QUINTIN BAY
30°
25°
PACIFIC OCEAN
30°30'N
El Chute
30°25'N
Pacific Ocean
saltmarsh
mudflat
seagrass
lagoon channel
0
5
10
Km
30°20'N
116°00'W
115°55'W

Fig. 1. Location of the sampled area inside San Quintin Bay, Baja California, Mexico (modified from Ibarra-Obando et al. 2004).

Reish 1963; Barnard 1964; Cook 1974; Calderón-Aguilera and Jorajuira-Corbo 1986; Bretado-Aguirre 1987; Cantú-Martínez 1987; Griffis and Chavez 1988; Díaz-Castañeda and Rodríguez-Villanueva 1998), and at the community level (Barnard 1970; Calderon-Aguilera 1992; Sinicrope-Talley et al. 2000). Environmental conditions that play a role with the macro-infaunal (animals ≥ 0.3 mm) distribution inside San Quintin Bay include: distance from the mouth, gradients of tidal amplitude, changing hydrodynamics, seasonal runoff, and a breakdown of the typical inverse-estuary currents by overriding unidirectional winds (Sinicrope-Talley et al. 2000).

Oyster aquaculture, low-density tourism and fisheries are the main economic activities, none of which has significantly negatively impacted the bay up to this point. Doubling of aquaculture and construction of tourist mega-resorts are potential threats for the next decade (Aguirre-Muñoz et al. 2001).

Field Work

Samples were collected from the west arm, Bahia Falsa, in front of the fish camp known as "El Chute" (Fig. 1). Sampling took place in April, May, July, August, October, and November, 1993. Fauna associated with eelgrass were collected at high tide with a trawl net with metal frame of 0.4 × 0.5 m (2.54 cm mesh size) with a cod end of 1 mm mesh size. Each trawl lasted one minute at a constant speed of one knot, and covered about 15 m^2. A total of six trawls were done during the study period (one each sampled month). In the field, samples were fixed in 10% formaldehyde, and transported to the laboratory in buckets.

In the laboratory, samples were rinsed several times with fresh water, and plant material was separated from animal material. Seagrass leaves, roots, and macroalgae were washed in sieves of 2 and 1 mm. Once the organisms were separated, they were placed in glass jars, preserved in 70% isopropyl alcohol, counted under the microscope, and identified with taxonomic keys for each group. Biomass, as dry weight (DW), was obtained by drying organisms in an oven at 105°C for 12–24 hrs. Large organisms were cut into small pieces and once dried, the material was homogenized in a blender, and 4 or 5 sub samples were used for AFDW determination. The ash free dry weight biomass (AFDW) was determined after burning the dry organisms in a muffle furnace at 550°C for 4–6 hrs (Brower and Zar 1977). Biomass per trawl and per m^2 was determined.

Eelgrass samples were collected from a 4.8 ha mudflat in front of "El Chute", along a 300 m long transect in the intertidal (-0.10 m with respect to Mean Lower Low Water, MLLW). Sampling took place at every spring tide. To assess eelgrass biomass, 7 random samples were collected using a 0.04 m^2 quadrat on each sampling date. Only aboveground material was collected. Samples were washed with seawater, using a 1 mm mesh sieve. All material was placed in labeled plastic bags and kept cool until transported to the laboratory. Rinsed samples were sorted to calculate shoot density. Aboveground material was processes as described in Poumian-Tapia and Ibarra-Obando (1999).

Data Analysis

For each sample, univariate community measures were determined: abundance (number of individuals, N), richness (number of species, N0), diversity (N1), evenness (Pielou's J′), and dominance (Krebs 1985). Relative abundances and densities for each species in each sample were also obtained. Diversity was measured by Hill indices (Hill 1972), as they take into account the Shannon-Weaver diversity index, and the Simpson diversity index:

$N0 = S$; $N1 = e^{H'}$; $N2 = 1/\lambda$; where

S = number of species; H' = Shannon Index; λ = Simpson Index

As the Shannon-Weaver index and the Simpson index are affected by sample size, and number of organisms per sample, their joint use can reduce the bias in diversity assessment (Hill 1972). Dominance of the different species was estimated using the Importance Value Index (I.V.I.) that combines three determinant characteristics of the importance of any given species in the community: abundance, frequency and biomass (Krebs 1985):

$I.V.I = \%N + \%F + \%B$, where

$\%N$ = relative abundance; $\%F$ = relative frequency;

$\%B$ = relative biomass

In order to identify differences and similarities in epifaunal community composition between samples, we performed a Non-metric Multidimensional Scaling (MDS) (Ludwig and Reynolds 1988). For this purpose, data were organized into abundance, and presence-absence matrices that were simplified by eliminating those species present in only one sample ($F<16\%$), and in relatively low abundances ($<0.001\%$ of sample total abundance) (Stephenson and Cook 1980). Total abundance data were transformed to the 4th root of n to reduce the variability between values (Clarke and Green 1988). Seasonal variations were analyzed with a two-way nested Analysis of Similarity and (ANOSIM) test (Clarke and Warwick 1994), in which months were nested in seasons. For all tests, confidence level was set at 0.05.

The relationships between epifauna richness, and abundance, and eelgrass density and aboveground biomass were analyzed with a Rank Correlation Analysis (Zar 1966).

Results

Univariate Measures of Community Composition

The average number of organisms per trawl was 52,836±16,703 (±1 S.E.), representing 74 taxa belonging to four major groups: polychaetes, crustaceans, mollusks, and fishes. At the group level, species richness was highest for polychaetes and crustaceans, with 24 species each, representing 32% of the total species richness. Amphipods were the most frequent crustacean taxa, accounting for 15 of the 24 identified taxa. Fishes represented only 11% of the total, with 8 species. Of the 317,015 organisms collected, mollusks contributed 71% of the total abundance, followed by crustaceans, with 28%. Crustaceans and fish had the highest biomass, about 37% each (Table 1).

Of the 74 taxa collected, the 6 most abundant species were the mollusk, *Assiminea dubiosa*; the caridean, *Hippolyte californiensis*; the amphipods, *Amphitoe plumosa, Corophium baconi, Hyale nigra* and *Erichtonius brasiliensis*. The mollusk *A. dubiosa* represented 70% of the total abundance, and was the only species present in all samples. The next numerically important species was *H. californiensis* making up 5% of the total number of individuals. The four most abundant and common polychaete species and their total abundance per trawl were as follows: *Platynereis bicanaliculata* (2,280); *Polydora cirrosa* (207); *Exogone lourei*

Table 1. Richness, abundance, and biomass values and percentages for each epifaunal group found in San Quintin Bay between April and November 1993. Values represent the total of 6 trawls. NO = number of species; N = number of individuals. Biomass is expressed as g of Ash Free Dry Weight (AFDW).

	Richness		Abundance		Biomass	
Group	NO	%	N	%	g (AFDW)	%
Polychaetes	24	32.4	2,855	0.9	0.44	0.2
Crustaceans	24	32.4	88,981	28.06	87.5	36.5
Mollusks	18	24.3	224,672	70.8	63.6	26.6
Fishes	8	10.8	507	0.16	87.9	36.7
Total	74	99.9	317,015	99.9	239.4	100

(142), and *Eulalia bileneata* (105). The dominating abundance of the first species is evident.

The species with highest biomass was *H. californiensis,* comprising 32% of the total biomass, followed by *A. dubiosa* with 15%. Two fish species, *Syngnathus leptorhynchus,* and *Embiotoca jacksoni* had a similar contribution to total biomass (12%). The remaining 70 species had biomass values that represented between 7 and <1% of the total.

According to the I.V.I., the community was dominated by the following species: *A. dubiosa,* 88.5; *H. californiensis,* 40.1; *S. leptorhynchus,* 15.2; *E. jacksoni,* 13.8, and *H. nigra,* 10.0.

Values for the different community descriptors for each sampling time are presented in Table 2. No clear trends could be identified, given the limited number of trawls performed during this study.

Multivariate Measures of Community Composition

Ordination analysis using total abundances showed three well defined groups, which correspond to spring (April–May), summer (July–August), and autumn (October–November). The highest similarity was for the summer samples (80%) (Fig. 2). Spring and autumn groups were defined by *A. dubiosa* and *H. californiensis.* During summer, besides *A. dubiosa,* amphipods of the order Gammaridea (e.g. *Corophium baconi, Erichtonius brasilensis, H. nigra*) made a significant contribution (Table 3).

Plant–animal Relationships

A significant positive correlation between epifaunal diversity and eelgrass aboveground biomass was observed ($r = 1$, $p<0.05$), but no other significant

Table 2. Values obtained for the different community descriptors on each sampling date.

	April	May	July	August	October	November
Abundance (N)	63,526	45,673	60,734	73,913	46,448	26,721
Species richness (NO)	27	34	37	37	35	53
Diversity (N1)	1.50	2.49	4.28	5.08	2.76	4.05
Eveness (J′)	0.12	0.26	0.40	0.45	0.29	0.35
Biomass (B)	30.62	76.47	31.87	19.71	58.89	21.90

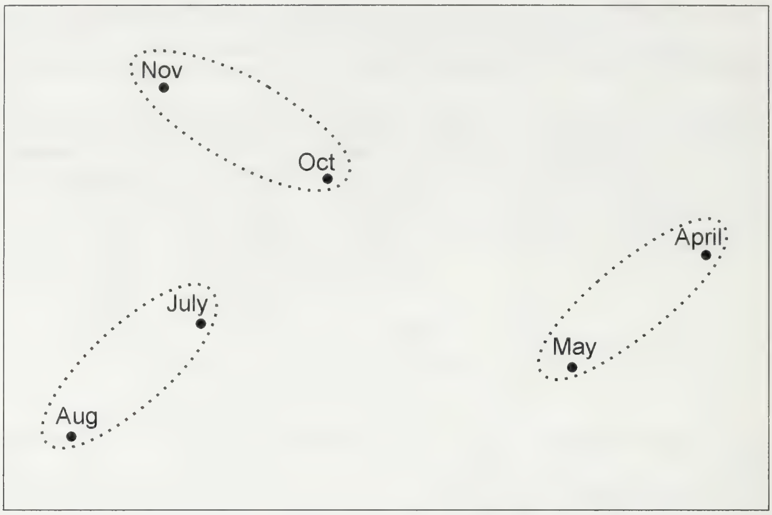

Fig. 2. MDS plot showing the relationship between samples using the simplified matrices of abundance.

correlations were identified. Changes in amphipods and polychaetes abundance seemed to follow those of eelgrass aboveground biomass (Fig. 3a and b).

Discussion

The four major groups that constitute the epifaunal community in San Quintin Bay played different roles in characterizing the community: mollusks were the most abundant; polychaetes and crustaceans both had the largest numbers of spe-

Table 3. Species that determine 50% of sample similarity based on abundance (individuals per trawl).

Seasonal Group	Taxon	Contribution (%)	Cumulative %
Spring	*A. dubiosa*	20.15	20.15
	H. californiensis	10.83	31.33
	E. brasilensis	5.93	37.26
	C. baconi	5.60	42.86
	Rhachotropis inflata	5.54	48.4
	Amphilochus neapolitanus	5.35	53.75
Summer	*A. dubiosa*	14.05	14.05
	H. nigra	9.14	23.19
	A. plumosa	8.13	31.32
	C. baconi	7.18	38.50
	E. brasiliensis	6.24	44.74
	R. inflata	5.75	50.49
Autumn	*A. dubiosa*	14.25	14.25
	H. californiensis	8.43	22.68
	E. crenulata	7.04	29.72
	H. nigra	6.68	36.40
	A. plumosa	6.20	42.60
	C. baconi	4.81	47.41
	P. bicanaliculata	4.61	52.02

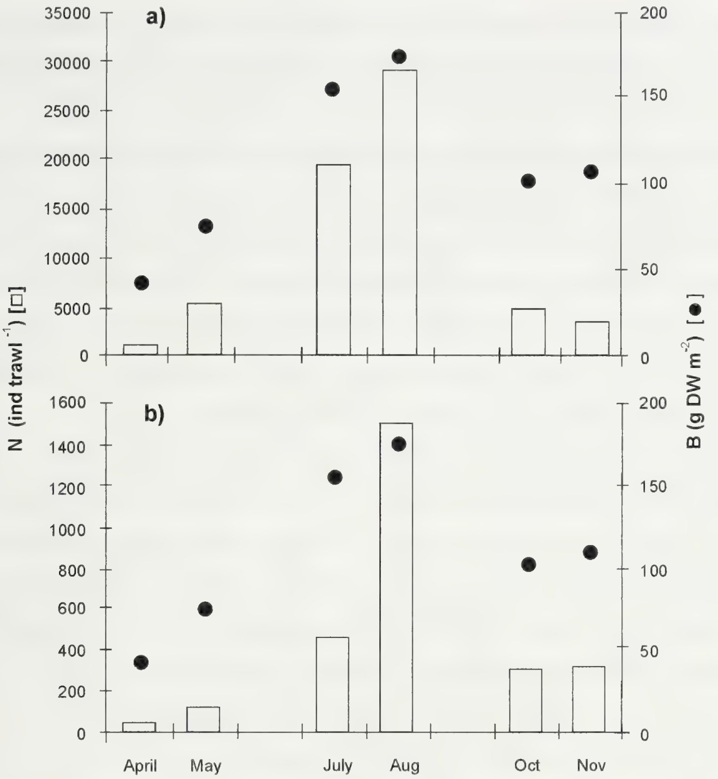

Fig. 3. Seasonal patterns of (a) amphipods abundance (individual trawl^{-1}) [□], and eelgrass biomass (g DW m^{-2}) [●]; (b) polychaete abundance (individual trawl^{-1}) [□], and eelgrass biomass (g DW m^{-2}) [●].

cies; and crustaceans and fishes had the highest biomass. Community composition differed over time, with the summer assemblage having the highest similarity. Finally, amphipod and polychaete abundances seemed to follow the seasonal variations in eelgrass aboveground biomass.

Mollusks represented 71% of total abundance in San Quintin Bay. Similar high percentages have been reported in other eelgrass beds (e.g. Marsh 1973; Thayer et al. 1975), as well as in beds of other seagrass species (e.g., Virnstein and Howard 1987; Nakaoka et al. 2001). As an example, in the eelgrass beds of North Carolina, gastropods represented up to 72% of the total numbers of epifauna found in the ecosystem (Thayer et al. 1975).

We found high species richness for polychaetes, and crustaceans (Table 1). Reish (1963), Calderón-Aguilera (1992), and Díaz-Castañeda and Rodríguez-Villanueva (1998) report similar results for polychaetes in San Quintin Bay. Similar results were reported by Gambi et al. (1992), Colognola et al. (1984), and Mazella et al. (1989) in a *Posidonia oceanica* bed in the Gulf of Naples. Crustaceans were the second group with high species richness in our study site. A high crustacean richness (46%) was also reported for San Quintin Bay by Villareal (1995), and by for a mixed *Zostera* bed in Otsunhi, Japan (56%) by Nakaoka et al. (2001).

The high contribution of crustaceans to epifaunal biomass that we found during this study, about 37%, has also been noted for other sites. For the *Heterozostera tasmanica* beds in Western Port, Australia, Edgar et al. (1994) found that the large contribution of crustaceans to biomass was influenced by the presence of eight large filter-feeding brachiopods.

Seasonal differences in epifaunal community abundance in eelgrass beds, with peak values during summer, have been reported by Thayer et al. (1975), Heck and Orth (1980b), and Orth and Heck (1980). Edgar (1990) reported a similar pattern in *Amphibolis* beds, and Coles et al. (1993) found the same trend for eight species seagrass beds in Cairns Harbour, Australia. With the limited data set that we have at present for San Quintin Bay we are unable to describe seasonal variations; however, the MDS test on total abundance identified three groups corresponding to spring, summer and autumn respectively (Fig. 2), with the summer group having the highest similarity (ANOSIM test).

During our study, amphipods made an important contribution to the definition of the summer group, as they reached their maximum abundance and biomass during this season (Table 3). This seasonal pattern differs from the one reported by Nelson (1979), in Beaufort, North Carolina, who found amphipod density, number of species, and diversity to be low in July–August, and higher in January–February. Nelson (1979) suggested that the observed amphipod change was the result of predation by the pinfish *Lagodon rhomboides.* In San Quintin Bay, *S. leptorhynchus* has been described as the most abundant fish species, attaining its maximal abundance in May and November (Rosales-Casián 1997). This difference in life cycle between the fish (predator) and the amphipods (prey) could help explain the differing periods of peak abundance and biomass for these two localities.

Applying univariate community measures in the intertidal *Zostera novazelandica* beds in northern New Zealand, Turner et al. (1999) found few consistent seasonal or annual trends over a two-year period. Multivariate analysis (Canonical Correspondence Analysis) applied at the scale of the patches revealed that spatial structure explained 1–2% of the variation in species abundance, environmental variables explained 3–4%, temporal variability explained 12–14%, and 75% of the variation remained unexplained. Turner et al. (1999) attributed the large contribution of temporal variability to the explained variance as a reflection of the seasonal and annual trends in the number of individuals, and in the species present. Our data for San Quintin Bay also seem to reflect a high temporal variability and could indicate the existence of ephemeral assemblages that change in response to a complex set of physical and biological variables, including the annual variations in eelgrass aboveground biomass.

The high abundance of a few dominant species that we found during this study, with six species accounting for 93% of the total abundance, is similar to what has been reported for other seagrass beds. For example, Marsh (1973) in the eelgrass beds of the York River, Virginia, found that the five most abundant species accounted for about 60% of the total. Heck and Orth (1980a) in the eelgrass beds of the Lower Chesapeake Bay, found that six species of macroinvertebrates made up nearly 68% of the total.

We cannot compare our absolute values of epifaunal abundance and richness with those reported by other authors, because sessile, creeping or walking epifauna are not collected reliably by trawling (Heck and Orth 1980a). As a consequence, our values represent underestimations of abundance and richness. A further limitation we faced was the reduced number of trawls and the lack of replicates to assess the within-month variability. As a result, the information provided in this study should be considered preliminary.

While some authors have found a good relationship between plant-animal density and biomass (e.g. Heck and Orth 1980b; Orth and Heck 1980; Stoner 1980; Lewis and Stoner 1983; Edgar and Robertson 1992; Webster et al. 1998), others have not (e.g. Virnstein and Howard 1987; Edgar 1999). For San Quintin Bay, Sinicrope-Talley et al. (2000) found a correlation between the presence of *Zostera* and a few taxa of macrofauna, but only in combination with sediment properties. Our data show a significant positive correlation between epifaunal diversity and eelgrass aboveground biomass. Amphipod and polychaete seasonal trends seemed to match the seasonal change in eelgrass aboveground biomass (Fig. 3a and b). These results seem to indicate an association between the above-mentioned epifaunal species and eelgrass leaves, and can be compared with the diverse, leaf-associated faunal assemblage that Edgar and Robertson (1992) described in the *Amphibolis* beds at Seven Mile Beach, Australia, which was negatively affected by seagrass thinning. For mixed seagrass beds in North Carolina, Hovel et al. (2002) found that seagrass shoot biomass strongly influenced shrimp densities in 1992, but no correlation was found the previous year. We are aware of the extreme variability of the above-mentioned relationships for San Quintin Bay, and of the need for repeated samplings to establish reliable plant-animal associations. Hovel et al. (2002) found that different faunal species or species groups may respond to different aspects of seagrass habitats, and concluded that the high variability in seagrass landscape structure does not necessarily correspond to variability in faunal abundance. Rather, myriad processes operating at a variety of scales make relationships between fauna and environmental variables complex and difficult to predict.

Conclusions

The epifaunal community in San Quintin Bay was characterized by the high abundance of a few dominant species. Different assemblages were present throughout the study period, reflecting the seasonal changes of the various species present, as well as the changes in environmental conditions. The summer group had the highest similarity. Polychaetes and amphipods seemed to follow the seasonal changes in eelgrass aboveground biomass.

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This meeting was a Joint Meeting between the Southern California Academy of Sciences and **The Society of Environmental Toxicology and Chemistry (SETAC). Phillip Markle** of SETAC was instrumental in coordinating our efforts and organizing the SETAC portion of the meeting.

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Research Training Program

Abstracts 125 to 144 represent the final product of the high school Research Training Program for 2004-05.

The following students were selected to receive an honorary membership in the American Association for the Advancement of Sciences: Da Ium Im, Joon-Bok Lee, Julie A. Guerin and Carol Y. Suh.

Based on their oral presentation and research paper, the following students were invited to present their work at the American Junior Association of Science meeting, held in conjuction with the A.A.A.S. meeting in February, 2005 in Washington, D.C.; Da Ium Im, Joon-Bok Lee, Julie A. Guerin, Carol Y. Suh, Lisa Calfas, Daniel Chin, David Lluncor, Su Fey Ong, Geoffrey Woo, and Swati Yanamadala.

We would like to acknowledge the Harbor Association of Industry and Commerce for generously supporting our Research Training Program.

STUDENT AWARD WINNERS AT THE 2005 ANNUAL MEETING

At the 2005 Annual Meeting, the following student papers and posters won awards.

Awarded by the Southern California Academy of Sciences

Best Posters:

Physical Science: Ami Jenkins. Pasadena City College
PRELIMINARY ANALYSIS OF A CAVE FAUNA FROM SAN QUINTIN, BAJA MEXICO.

and **Gregorio Pacheco-Ambriz**. Pasadena City College
CACHE OF FOSSIL REMAINS FOUND IN SAN QUINTIN, BAJA CALIFORNIA LOCATED WITHIN A BEACH CLIFF CAVE

Ecology and Evolution: Andres Carillo. CSU Fullerton

THE EFFECTS OF ARTICHOKE THISTLE (*CYNARA CARDUNCULUS*) DENSITY AND COASTAL SAGE SCRUB INFLUENCE ON PREDATION OF ARTIFICIAL NESTS.

Best Poster, Molecular/physiological: P. Jensen. ***U. California Riverside***

INDIVIDUAL AND JOINT EFFECTS OF SELENATE AND METHYLMERCURY ON A TERRESTRIAL INSECT DETRITIVORE.

Best Papers

Ecology/Evolution: R.A. Ellingson. CSU Los Angeles
BORN AND RAISED IN SOUTHERN CALIFORNIA: DEVELOPMENTAL EVOLUTION AND CRYPTIC SPECIATION IN THE SEA SLUG GENUS *ALDERIA*.

Ecology/Evolution: Tom Benson. CSU San Bernardino

POPULATION GENETICS OF PYGMY NUTHATCHES IN SOUTHERN CALIFORNIA

Fisheries: Andrew C. Davenport. San Diego State University

POSITIVE INDIRECT EFFECTS OF REEF FISHES ON GIANT KELP PERFORMANCE

Best Paper: Awarded by the American Institute of Fishery Research Biologists

B.V. Ziegler. CSU Long Beach
BEHAVIORAL THERMOREGUALTION OF THE LEOPARD SHARK (*TRIAKIS SEMIFACIATA*) IN THE NEARSHORE EMBAYMENTS OF SANTA CATALINA ISLAND, CALIFORNIA.

Southern California Academy of Sciences 2005 Session Schedule

Friday, May 20, 2005
Location: Hilton Business Center, Room 100

Session: Wetland Restoration/Ecology

Chair: Katherine Prickett

8:30 **TOUR OF THE BALLONA FRESHWATER MARSH PROJECT.**

1 10:00 **SOUTHERN CALIFORNIA WETLAND RECOVERY PROJECT–A REGIONAL APPROACH TO WETLAND RECOVERY.** **Mary Small**, State Coastal Conservancy.

2 10:20 **BALLONA WETLANDS–COMMUNITY BASED RESTORATION PLANNING.** **Mary Small**, State Coastal Conservancy.

10:40–11:00 **BREAK**

11:00–11:30 **Welcome, Student Grant Awards.**

11:30–12:30 **Plenary Talk: Dr. Brian Fagan: Fish on Friday: How the Catholic Doctrine of eating Fish on Friday changed History.**

3 12:30–1:20 **LUNCH BREAK**

1:20 **ORMOND BEACH: RESTORATION OF HISTORIC WETLANDS.** **Peter Brand.** State Coastal Conservancy.

4 1:40 **THE MALIBU LAGOON ENHANCEMENT PROJECT.** **C.S. Shuman.** Heal the Bay, 3220 Nebraska Ave., Santa Monica, CA, 90404.

5 2:00 **ECOSYSTEM RESTORATION AT TIJUANA ESTUARY, CALIFORNIA.** **Chris Nordby.** Tierra Environmental Services, 9915 Businesspark Avenue, Suite C, San Diego, CA 92131.

6 2:20 **ON A RESTORING WETLANDS GRASSROOTS LEVEL–NON-PROFITS AND WETLAND RESTORATION.** **D. Gibson.** San Elijo Lagoon Conservancy Executive Director/Principal Scientist, Encinitas, CA 92023.

7 2:40 **THE JOURNEY FROM WETLANDS TO OIL FIELD AND BACK.** **Jim Trout.** State Lands Commission.

3:00–3:20 **BREAK**

8 3:20 **ENGINEERING OF THE BOLSA CHICA WETLANDS RESTORATION PROJECT.** **Chris Webb**, Michael McCarthy, Moffatt & Nichol; Jack Fancher, U.S. Fish and Wildlife Service; and Keith Merkel, Merkel & Associates.

9 3:40 **USING SPATIALLY-EXPLICIT MODELS TO PREDICT EELGRASS DISTRIBUTION FOR RESOURCE MANAGEMENT AND RESTORATION.** **Robert Mooney.** Merkel and Associates Inc.

10 4:00 **EVALUATING THE SUCCESS OF WETLAND MITIGATION IN LOS ANGELES AND VENTURA COUNTIES: ASSESSING PERMIT COMPLIANCE AND WETLAND CONDITION.** **R.F. Ambrose** and S.F. Lee. Environmental Science and Engineering Program and Department of Environmental Health Sciences, University of California, Los Angeles, CA 90095-1772.

11 4:20 **DEVELOPMENT OF AN INTEGRATED REGIONAL ASSESSMENT PROGRAM FOR SOUTHERN CALIFORNIA WETLANDS.** **E.D. Stein**, M. Sutula, and A.E. Fetscher. Southern California Coastal Water Research Project, 7171 Fenwick Lane, Westminster, CA 92683.

12 4:40 **MONITORING PLAN FOR THE SAN DIEGUITO LAGOON RESTORATION PROJECT.** **Page, H. M.**, S. C. Schroeter, D. C. Reed, R. F. Ambrose, and M. A. Steele. Marine Science Institute, University of California, Santa Barbara, CA, 93106, Environmental Science and Engineering Program, University of California, Los Angeles, CA, 90095.

Friday, May 20, 2005
Location: Hilton Business Center, Room 103

Session: Ecology of Nearshore Reefs

Chair: Daniel Pondella, Occidental College and Bob Grove, S.C Edison

13 8:40 **QUANTIFYING THE PERFORMANCE OF DIFFERENT REEF DESIGNS ON KELP BED FISH AND BENTHIC COMMUNITY DEVELOPMENT AT THE SAN CLEMENTE EXPERIMENTAL ARTIFICIAL REEF.** **Dan Reed**[1], Stephen Schroeter[1], David Huang[1], Todd Anderson[2], and Robert Grove[3]. [1]Marine Science Institute, University of California, Santa Barbara, CA 93106. reed@lifesci.ucsb.edu; [2]Department of Biology, San Diego State University, San Diego CA 92182; [3]Southern California Edison Company, Rosemead, CA 91770. grovers@sce.com.

14 9:00 **EVALUATION OF KELP (*MACROCYSTIS PYRIFERA* (L.) C. AGARDH) KELP RESTORATION OFF TAJIGUAS, CALIFORNIA USING SCATTERED GRANITIC BOULDERS IN A SAND HABITAT.** **D. C. Barilotti**, D. C. Lees and D. M. Schroeder. Sea Foam Enterprises, San Diego CA 92107, seafoam@mindspring.com; Littoral Ecological & Environmental Services, Leucadia, CA 92024, dennislees@earthlink.net; Marine Science Institute, UCSB, Santa Barbara 92106, schroed@lifesci.ucsb.edu.

15 9:20 **"FLOATING" BEHAVIOR OF GRANITIC BOULDERS USED TO CONSTRUCT THE TAJIGUAS KELP HABITAT ON A SAND PLAIN AND COMPARISON OF THE DEVELOPING EPIBIOTIC INVERTEBRATE ASSEMBLAGE WITH NEARBY NATURAL REEF ASSEMBLAGES.** **Dennis C. Lees** and D. Craig Barilotti. Littoral Ecological & Environmental Services, Leucadia, CA 92024 and Sea Foam Enterprises, San Diego, CA 92107.

16 9:40 **COMPARISON OF REEF FISH ASSEMBLAGES AMONG NATURAL ROCK HABITATS AND THE CREATED TAJIGUAS KELP HABITAT IN THE SANTA BARBARA CHANNEL.** **D. M. Schroeder** and D. C. Barilotti. Marine Science Institute, University of California, Santa Barbara, CA 93106, schroed@lifesci.ucsb.edu; and Sea Foam Enterprises, 4369 Osprey Street San Diego CA 92107.

17 E 10:00 **POSITIVE INDIRECT EFFECTS OF REEF FISHES ON GIANT KELP PERFORMANCE.** **Davenport, Andrew C.** San Diego State University.

18 10:20 **MARINE RESERVE DESIGN: DETERMINING AN OPTIMAL SIZE AND LOCATION.** **P.E. Parnell**[1], Paul K. Dayton[1], and Cleridy Lennert-Cody[2]. [1]Scripps Institution of Oceanography, UCSD, La Jolla, CA 92093-0227; [2]Inter-American Tropical Tuna Commission, 8604 La Jolla Shores Drive, La Jolla, CA 92037-1508.

10:40–11:00 **BREAK**

11:00–11:30 **Welcome, Student Grant Awards.**

11:30–12:30 **Plenary Talk: Dr. Brian Fagan: Fish on Friday: How the Catholic Doctrine of eating Fish on Friday changed History.**

12:30–1:40 **LUNCH BREAK**

19 F 1:40 **BEHAVIORAL THERMOREGUALTION OF THE LEOPARD SHARK (*TRIAKIS SEMIFACIATA*) IN THE NEARSHORE EMBAYMENTS OF SANTA CATALINA ISLAND, CALIFORNIA.** **B.V. Ziegler**, California State University Long Beach, Department of Biological Sciences, Long Beach, CA, 90840-3702.

20 E 2:00 **MOVEMENT PATTERNS AND HABITAT USE OF OCEAN WHITEFISH (BRANCHIOSTEGIDAE) IN A SANTA CATALINA ISLAND MARINE RESERVE.** **Bellquist, L.F.**[1], C.G. Lowe[2], and J.E. Caselle[3]. [1,2]California State University Long Beach, Department of Biological Sciences, Long Beach, CA 90840; [3]Marine Science Institute, University of California Santa Barbara, Santa Barbara, CA 93106.

21 2:20 **THE FISH ASSEMBLAGE S OF AN ARTIFICIAL AND NATURAL REEF IN THE HORSESHOE KELP.** **J.T. Froeschke**[1], B.M. Haggin[2], D.J. Pondella[1] and L.J. Allen. [1]Vantuna Research Group, Occidental College, Department of Biology, Los Angeles, CA, 90041; [2]Nearshore Marine Fish Research Program, California State University, Northridge, Department of Biology, Northridge CA, 91330.

22 2:40 **EFFECTS ON NEARSHORE ROCKY REEFS FOLLOWING THE REGIONAL BEACH SAND PROJECT.** **L. Honma**[1], B. Snyder[2], and R. Rundle[3]. [1]Merkel & Associates, 5434 Ruffin Rd, San Diego, CA 92123; [2]AMEC Earth & Environmental, 5510 Morehouse Dr., San Diego, CA 92121; [3]San Diego Association of Governments (SANDAG), 401 B Street Suite 800, San Diego, CA 92101.

3:00 **BREAK**

23 3:20 **EVALUATION OF EELGRASS MITIGATION AND FISHERY ENHANCEMENT STRUCTURES IN SAN DIEGO BAY, CALIFORNIA.** **D. J. Pondella, II**[1], L. G. Allen[2], M. T. Craig[3] and B. Gintert[4]. [1]Vantuna Research Group, Department of Biology, Occidental College, Los Angeles, CA 90041; [2]Department of Biology, California State University, Northridge, CA 91330-8303; [3]Scripps Institution of Oceanography, La Jolla, CA 92093-0208; [4]Rosenstiel School of Marine and Atmospheric Science, Marine Biology and Fisheries Division, Miami, FL 33149.

24 3:40 **LESSONS LEARNED, A HALF-CENTURY OF GIANT KELP RESTORATION IN SOUTHERN CALIFORNIA.** **Mike Curtis.** MBC Applied Environmental Sciences.

25 E 4:00 **GIANT KELP RESTORATION AND MONITORING IN SANTA MONICA BAY.** **T. Ford.** Santa Monica Baykeeper, P.O. Box 10096, Marina del Rey, CA 90295.

Friday, May 20, 2005
Location: Hilton Business Center, Room 107

Session: Contributed Papers

Chair: Don Buth, UCLA

26 M 9:00 **COMPARISON OF DIGESTIVE ENZYME ACTIVITIES IN TUNAS AND THEIR ECTOTHERMIC RELATIVES.** **D. L. Neumann** and K. Dickson. California State University, Fullerton, Department of Biology, Fullerton, CA, 92831.

27 E 9;20 **STRUCTURAL COMPLEXITY OF SEAGRASS INFLUENCES PATTERNS OF RECRUITMENT OF FISHES IN SAN DIEGO BAY.** **Lipski, D.M.** San Diego State University, San Diego, CA, 92182.

28 9:40 **TRANSITIVITY AND SONG PREFERENCES IN THE HOUSE CRICKET, *ACHETA DOMESTICUS*.** **Sean E. Walker**[1] and J. Andrew Roberts[2]. [1]Department of Biological Science, California State University Fullerton; [2]Department of Evolution, Ecology, and Organismal Biology, The Ohio State University, Newark.

29 9:40 **ACOUSTIC TRACKING AND MONITORING OF CULTURED JUVENILE WHITE SEABASS RELEASED INTO SOUTHERN CALIFORNIA EMBAYMENTS.** **M. A. Shane**[1], M. A. Drawbridge[1], and H. C. Simonds[2]. [1]Hubbs-SeaWorld Research Institute, 2595 Ingraham Street, San Diego, CA, 92109; [2]San Diego State University Foundation, 5250 Campanile Drive, San Diego, CA 92182.

30 M 10:20 **LACTATE PROCESSING IN ENDOTHERMIC AND ECTOTHERMIC SHARKS.** **J.M. Backey** and K.A. Dickson. California State University, Department of Biological Science, Fullerton, CA, 92831.

Friday, May 20, 2005
Location: Hilton Business Center, Room 107

Session: Archaeology and Paleontology of Southern California

Chair: Andrea P. Murray, California State University, Fullerton

31 1:40 **LATE PREHISTORIC CERAMIC PRODUCTION IN THE UPPER MOJAVE RIVER REGION, SAN BERNADINO COUNTY, CALIFORNIA.** **B. Travis.** Department of Anthropology, California State University, Fullerton, CA 92831.

32 2:00 **ARCHAEOFAUNAL RESEARCH AT LATE HOLOCENE PREHISTORIC SITES ON SAN NICOLAS ISLAND: RECENT EXCAVATIONS AND EXPERIMENTAL STUDIES.** **Steven R. James** and James R. Wallace. Department of Anthropology, California State University at Fullerton, P.O. Box 6846, Fullerton, CA 92834-6846.

33 2:20 **ARCHAEOLOGY AT THE HARVARD HILL SITE, SAN BERNARDINO COUNTY, CALIFORNIA.** **J.A. McKenna.** McKenna et al., Whittier, CA 90601-3724.

34 2:40 **TWO RITUAL CACHES FROM CA-ORA-950: A WINDOW ONTO THE SYMBOLOGY OF COGGED STONES.** **H. C. Koerper.** Cypress College, Cypress, CA 90630.

3:00 **BREAK**

35 3:20 **PREHISTORIC ADAPTATIONS TO COASTAL WETLANDS: AN 8,000 YEAR VIEW FROM SANTA MONICA BAY, WEST LOS ANGELES.** **John G. Douglass,** Jeffrey H. Altschul, Richard Ciolek-Torrello, Benjamin R. Vargas, and Donn R. Grenda. Statistical Research, Inc. 21 West Stuart Ave Redlands, CA 92373.

36 3:40 **OPTIMAL RESOURCE PRODUCTION: A MODEL OF CHUMASH IMPACT ON THE ENVIRONMENT IN THE SANTA BARBARA CHANNEL AREA.** **Edgar H. Huerta.** Department of Anthropology, California State University, Fullerton, 800 N. State College Blvd, Fullerton, CA 92831.

37 4:00 **"JUNE GLOOM" AND "TULE FOG": CONSIDERATIONS OF THE IMPORTANCE OF CLOUD MOISTURE FOR PREHISPANIC SETTLEMENT AND SUBSISTENCE STRATEGIES IN SOUTHERN CALIFORNIA.** **Frederick W. Lange, PhD.** LSA Associates—Riverside Office.

38 4:20 **PALEOCLIMATE AND VEGETATION RECORD IN THE LATE PLEISTOCENE PALOS VERDES FORMATION ("OLDER ALLUVIUM") IN THE SAN FERNANDO VALLEY, SOUTHERN CALIFORNIA.** **L.H. Fisk.** PaleoResource Consultants, 5325 Elkhorn Boulevard, #294, Sacramento, CA 95842.

39 4:40 **REVISED CORRELATION AND AGE ASSIGNMENTS OF FOSSIL LAND MAMMAL ASSEMBLAGES OF LATE HEMINGFORDIAN TO EARLIEST HEMPHILLIAN (EARLY MIDDLE TO EARLY LATE MIOCENE) AGE IN CALIFORNIA, NEBRASKA, AND TEXAS, BASED ON OCCURRENCES OF TICHOLEPTINE OREODONTS (MAMMALIA, ARTIODACTYLA, OREODONTIDAE, TICHOLEPTINAE) AND OTHER LAND MAMMAL TAXA.** **E.B. Lander.** Paleo Environmental Associates, Inc., 2248 Winrock Avenue, Altadena, CA, 91001-3205.

Friday, May 20, 2005
Location: Hilton Business Center, Room 300
Time: 5–7 p.m.

Session: Poster Session and Social

40 P **CACHE OF FOSSIL REMAINS FOUND IN SAN QUINTIN, BAJA CALIFORNIA LOCATED WITHIN A BEACH CLIFF CAVE.** **G. Pacheco-Ambriz.** Baja California Independent Research Project, Pasadena City College, Department of Natural Science, Pasadena, CA 91003.

41 **ADSORPTION OF SYNTHETIC PYRETHROIDS ON SEDIMENT.** **S. Bondarenko,** S. Qin and J. Gan. Department of Environmental Sciences, University of California, Riverside, CA 92521.

42 M **SURVEY FOR SYNTHETIC PYRETHROIDS WITHIN THE SAN DIEGO/NEWPORT BAY WATERSHED.** **R.L. Budd,** S. Bondarenko, and J. Gan. University of California at Riverside, Riverside, CA 92521.

43 E **THE EFFECT OF FEMALE CHEMICAL CUES ON THE AGGRESSIVE BEHAVIOR OF MALE CRICKETS, *ACHETA DOMESTICUS*.** **Leslie J. Buena** and Sean E. Walker. Department of Biological Science, California State University, Fullerton. Fullerton, Ca 92831.

44 E **THE EFFECTS OF ARTICHOKE THISTLE (*CYNARA CARDUNCULUS*) DENSITY AND COASTAL SAGE SCRUB INFLUENCE ON PREDATION OF ARTIFICIAL NESTS.** **Andres Carrillo** and Leslie Buena. Department of Biological Science, California State University, Fullerton.

45 **SEWAGE IS AN UNLIKELY SOURCE OF FECAL INDICATOR BACTERIA IN THE LOWER SANTA ANA RIVER WATERSHED.** **D.L. Young,** J. A. Noblet[2], E. Y. Zeng[1,3] and S. Ensari[3]. [1]Southern California Coastal Water Research Project, Westminster, California; [2]California State University, San Bernardino, California; and [3]University of California, Irvine, California.

46 DESCRIPTION OF FIELD-COLLECTED LARVAE OF TWO NATIVE FRESHWATER SOUTHERN CALIFORNIA FISHES, *CATOSTOMUS SANTAANAE* AND *GILA ORCUTTI*. **Richard F. Feeney.** Natural History Museum of Los Angeles County, 900 Exposition Blvd.,Los Angeles, CA 90007; and **Camm C. Swift.** ENTRIX, Inc., 2140 Eastman Ave. Suite 200, Ventura, CA 93003.

47 E AXIAL SPLITTING OF SHRUBS IN WET AND DRY ENVIRONMENTS. **C. Goedhart**, G. Pongetti, S. Espino, J. Schenk. California State University, Fullerton, Department of Biology.

48 EVALUATION OF METHODS FOR DETERMINING CHRONIC TOXICITY IN MARINE SEDIMENTS. **D. Greenstein**[1], S. Bay[1], B. Anderson[2], B. Phillips[2], G. T. Chandler[3], D. Farrar[4], A. H. Ringwood[5], and C. Keppler[6]. [1]Southern California Coastal Water Research Project, Westminster CA; [2]University of California Davis, Monterey, CA; [3]University of South Carolina, Columbia, SC; [4]US Army Engineer Research and Development Center, Vicksburg, MS; [5]University of North Carolina–Charlotte, Charlotte, NC; [6]Marine Resources Research Institute, Charleston, SC.

49 E LACK OF GENDER-BIASED MICROSITE PATTERNS IN *SALIX LASIOLEPIS*. **Shannon Harsh** and **Allison Roth,** Dustin Taylor and Cheryl Swift. Whittier College, Department of Biology, Whittier, CA 90608.

50a E MORPHOLOGY AND MOLECULAR PHYLOGENY OF *EGREGIA MENZIESII*. **Henkel, S.K.,** G.E. Hofmann, and A.C Whitmer. Marine Science Program, Department of Ecology, Evolution, and Marine Biology, University of California, Santa Barbara 93106.

50b M BIOAVAILABILITY OF PERMETHRIN IN SEDIMENTS AND ESTIMATED WITH SOLID PHASE MICROEXTRACTION (SPME). **W. Hunter,** W. Yang, and J. Gan. University of California, Riverside, Riverside, CA 92521.

51 P PRELIMINARY ANALYSIS OF A CAVE FAUNA FROM SAN QUINTIN, BAJA MEXICO. **A.J. Jenkins.** Baja California Independent Research Project, Pasadena City College, Department of Natural Science, Pasadena, CA 91106.

52 M BOLUS REBOUND KINEMATICS DURING ENGULFMENT FEEDING IN THE RORQUAL WHALES. **B.W. Kot.** Department of Ecology and Evolutionary Biology, UCLA, Los Angeles, CA 90095.

53 THE GREATEST GRUNION HUNT IN 50 YEARS: CALIFORNIA GRUNION SIGHTINGS ACROSS THE SEASON AND ALONG THE COAST IN 2004. **K. Martin,** B. Cupp, and P. Johnson. Pepperdine University, Malibu, CA 90263-4321.

54 E INTERACTIONS OF NEARSHORE FISH ASSEMBLAGES AND NET-PEN MARICULTURE EFFORTS ON SANTA CATALINA ISLAND, CALIFORNIA. **C.T. Oakes** and D.J. Pondella, II. Vantuna Research Group, Occidental College, Department of Biology, Los Angeles, CA 90041.

55 A COMPARISON OF PREVALENCE AND MEAN INTENSITY OF THE ECTOPARASITE *ELTHUSA CALIFORNICA* IN SHINER SURFPERCH (*CYMATOGASTER AGGREGATA*) OF TOMALES AND BODEGA BAYS. **Pritchard, Justin,** Will Madrid, and Nick Weston-Swan. UCLA, Department of Ecology and Evolutionary Biology, Los Angeles, CA 90024.

56 ANALYSIS OF HISTORICAL CHLORDANE LEVELS IN SAN DIEGO AND MISSION BAY IN COMPARISON TO THE THRESHOLD LEVEL OF TOXICITY TO THE AMPHIPOD, *EOHAUSTORIUS ESTUARIUS*. **Y. Rodriguez**[1,2], J. Rudolph[2], C. Stransky[2]. [1]San Diego State University; [2]Nautilus Environmental, San Diego, CA.

57 SEASONAL BACTERIAL CONCENTRATIONS IN THE LONG BEACH/LOS ANGELES HARBOR COMPLEX; YEAR TWO OF A FIVE YEAR STUDY. **K.A Snow,** K.E. Flaherty, Y.J. Ralph, C.V. Wolfe, K. Kull and R.E. Pieper. Southern California Marine Institute, Terminal Island, CA 90731.

58 M INDEPENDENT AND JOINT TOXICITY OF PERCHLORATE AND HEXAVALENT CHROMIUM TO LARVAL MOSQUITOES. **M.A. Sorensen** and J.T. Trumble. University of California, Riverside, Riverside, CA 92521.

59 E VARIATION OF JOSHUA TREE MORPHOLOGY AMONG POPULATIONS IN THE EASTERN MOJAVE DESERT. **Tracy Valentovich** and Darren Sandquist. California State University, Fullerton. Fullerton, CA, 92831.

60 **ENDOCRINE DISRUPTION IN SOUTHERN COASTAL CALIFORNIA FLATFISH.** **D.E. Vidal**[1], J. Armstrong[2], M. Baker[3], J. Gully[4], M. Irwin[5], K.M. Kelley[6], D. Montagne[4], J. Reyes[6], D. Schlenk[5], S.M. Bay[1]. [1]Southern California Coastal Water Research Project, Westminster, CA; [2]Orange County Sanitation District, Fountain Valley, CA; [3]University of California at San Diego, La Jolla, CA; [4]Los Angeles County Sanitation District, Whittier, CA; [5]University of California at Riverside, Riverside, CA; [6]California State University at Long Beach, Long Beach, CA.

61 **HPLC COLUMNS WITH MODIFIED MONOSACCHARIDE DERIVATIVES AS CHIRAL SELECTOR.** **L. Wenjian**[1] and L. Tingyu[2]. [1] University of California, Riverside. CA. [2] Mississippi State University, Mississippi State, MS.

62 **BIOAVAILABILITY OF SYNTHETIC PYRETHROIDS IN SURFACE WATER.** **W. Yang**, W. Hunter, and J. Gan. University of California, Riverside, Riverside, CA 92521.

63 **STRAIN RELATEDNESS OF *CANDIDA* IN HUMANS: A URINARY PATHOGEN OR COLONIZER? (PHASE 1).** **Joon-Bok Lee.** California Academy of Math and Science and Division of Infectious Diseases, Los Angeles County Harbor-UCLA Medical Center, 1000 W. Carson Street, Torrance, California 90502.

64 **EFFECTS OF PHOSPHATE ON THE BIOLOGICAL PROCESSES OF TRICHODESMIUM.** **S.F. Ong**[1], J. Sohm[2], and D. Capone[2]. [1]California Academy of Mathematics and Science, Carson, CA; [2]Wrigley Institute of Environmental Biology, University of Southern California, Department of Biological Sciences, Los Angeles, CA.

65 **DETERMINATION OF BACTERIAL AND POLLUTANT FLOWS IN COASTAL ESTUARIES OF SOUTHERN CALIFORNIA.** **S. Yanamadala** and J. Dorsey. Chadwick School and Loyola Marymount University, Department of Natural Sciences, Los Angeles, CA, 90045.

66 **NEAR REAL-TIME DETECTION OF *ESCHERICHIA COLI* FOR MONITORING BEACH WATER QUALITY.** **J. Jay.** University of California, Los Angeles, Los Angeles, California.

67 M **INDIVIDUAL AND JOINT EFFECTS OF SELENATE AND METHYLMERCURY ON A TERRESTRIAL INSECT DETRITIVORE.** **P.D. Jensen** and J.T. Trumble, University of California, Riverside, Riverside, CA.

68 **HEAVY METALS IN THE CLAM *MEGAPITARIA SQUALIDA* FROM APPARENTLY POLLUTION-FREE ZONES IN BAJA CALIFORNIA, MEXICO: CONSIDERATIONS FOR HUMAN HEALTH EFFECTS.** **L. Méndez,** E. Palacios, B. Acosta, P. Monsalvo-Spencer, and S.C. Gardner. Centro de Investigaciones Biológicas del Noroeste, S.C., La Paz, Baja California Sur, Mexico.

69 **SUSCEPTIBILITY OF OXIDATIVELY CROSSLINKED β-AMYLOID PEPTIDES TO INSULIN DEGRADING ENZYME.** **J. Young.** Alhambra High School and USC Keck School of Medicine, School of Pharmacy, Department of Pharmaceutical Science, Los Angeles, CA, 90089.

Saturday, May 21, 2005
Location: Hilton Business Center, Rm. 103

Session: Fire Ecology

Chair: Ruth Wilson

8:50 **INTRODUCTION, RUTH WILSON**

71 9:00 **THE HISTORY OF WILDLAND FIRES IN AMERICA.** **R.J. Vogl.** Biology Department, California State University, Los Angeles 90032.

72 9:20 **ECONOMIC IMPACT OF WILDLAND FIRES.** **Armando González-Cabán.** USDA Forest Service, Pacific Southwest Research Station, Forest Fire Laboratory, 4955 Canyon Crest Drive, Riverside, California 92507.

73 9:40 **POST-FIRE EROSION IN THE SAN GABRIEL MOUNTAINS.** **P.M. Wohlgemuth.** USDA Forest Service, Pacific Southwest Research Station, 4955 Canyon Crest Drive, Riverside, CA 92507.

74 10:00 **NEW TRICKS ON THE OLD FIRE.** **Fujioka, Francis M.** USDA Forest Service, Forest Fire Laboratory, 4955 Canyon Crest Drive, Riverside, CA 92507.

75 10:20 **STRATEGIC FIRE MAPPING–TECHNOLOGY DEVELOPMENT FOR AIRBORNE REMOTE SENSING OF WILDLAND FIRES.** **Philip J. Riggan.** USDA Forest Service, PSW Research Station, 4955 Canyon Crest Drive Riverside, CA 92507.

10:40 **BREAK**

11:00 **Plenary Talk: Dr. James Powell: The Grand Canyon: Solving Earth's Grandest Puzzle.**

12:00–1:20 **LUNCH BREAK**

Saturday, May 21, 2005
Location: Hilton Business Center, Rm. 103

Session: Fire Ecology (Continued)

Chair: M. Narog

76 1:20 **CHANGES IN SPATIAL DISTRIBUTION AND ABUNDANCE OF BIRDS IN RELATION TO FIRE AND DROUGHT-INDUCED VEGETATION MORTALITY IN SOUTHERN CALIFORNIA.** **Rechel, Jennifer L.** USDA Forest Service, Pacific Southwest Research Station, Forest Fire Laboratory, Riverside, CA. USA 92507-6071.

77 1:40 **THE CONTRIBUTION OF FOREST INSECTS AND PATHOGENS TO TREE MORTALITY IN SOUTHERN CALIFORNIA MONTANE FORESTS.** **L.D. Merrill.** USDA Forest Service, 4955 Canyon Crest Drive, Riverside, CA 92507.

78 2:00 **WILDFIRE AFFECTS SOUTHERN CALIFORNIA RIPARIAN HABITAT.** **M. G. Narog,** C. J. Sclafani, and J. L. Beyers. USDA Forest Service, Pacific Southwest Research Station, Riverside, CA.

79 2:20 **SAN DIEGO FIRE RECOVERY NETWORK: WORKING AND LEARNING TOGETHER.** **M. McElhinney,** San Diego Fire Recovery Network; and A.S. Fege, San Diego Natural History Museum, Box 121390, San Diego, CA 92112.

2:40 **Concluding Panel; Marcia Narog.**

Saturday, May 21, 2005
Location: Hilton Business Center, Rm. 107

Session: Avian Research in Southern California

Chair: Kathy Keane, Keane Biological

80 8:40 **HOW ISLAND SCRUB-JAYS ATTAIN BREEDING STATUS IN LIMITED HABITAT.** **K. A. Corey,** C.T. Collins. U.S. Fish and Wildlife Service, Carlsbad Field Office, Carlsbad, CA 92009; Department of Biological Sciences, California State University, Long Beach, CA 90840.

81 E 9:00 **POPULATION GENETICS OF PYGMY NUTHATCHES IN SOUTHERN CALIFORNIA.** **T. A. Benson** and A. E. Metcalf. Department of Biology, California State University, 5500 University Parkway, San Bernardino, CA 92407.

82 9:20 **SEASONAL AND INTERANNUAL MOVEMENTS OF SALTON SEA-HATCHED BLACK SKIMMERS (*RYNCHOPS NIGER*).** **K. C. Molina** and K. L. Garrett, Natural History Museum of Los Angeles County, Los Angeles, CA 90007; C. T. Collins. California State University, Long Beach, CA 90840.

83 9:40 **OVER-WINTERING BEHAVIOR OF BLACK SKIMMERS IN SOUTHERN CALIFORNIA: SITTERS AND WANDERERS.** **C. T. Collins,** K. Molina and K. L. Garrett. Department of Biological Sciences, California State University, Long Beach, CA 90840; and Natural History Museum of Los Angeles County, 900 Exposition Blvd., Los Angeles, CA 90007.

84 10:00 **AVIAN EXTIRPATION AND COLONIZATION IN THE BALLONA VALLEY, LOS ANGELES COUNTY, CALIFORNIA.** **Daniel S. Cooper.** Audubon California, 11340 W. Olympic Blvd., Suite 209, Los Angeles, CA 90064.

85 10:20 **CHANGES IN BIRD SPECIES DIVERSITY FOLLOWING A SALTMARSH RESTORATION PROJECT AT BATIQUITOS LAGOON.** **K.M. Keane.** Keane Biological Consulting, 2892 N. Bellflower Blvd., Suite 480, Long Beach, CA 90815.

10:40–11:00 **BREAK**

11:00–12:00 **Plenary Talk: Dr. James Powell: The Grand Canyon: Solving Earth's Grandest Puzzle.**

12:00–1:20 **LUNCH BREAK**

Saturday, May 21, 2005
Location: Hilton Business Center, Rm. 107

Session: What's the Status of our Special-Status Bird Species?

Chair: Kathy Keane, Keane Biological

86 1:20 **SPECIAL STATUS BIRDS OF THE WHITTIER NARROWS BASIN, LOS ANGELES COUNTY.** **M.C. Long.** Los Angeles County Natural Areas, 1750 N. Altadena Dr., Pasadena, CA 91107.

87 1:40 **POPULATION STATUS OF ROYAL TERNS IN SOUTHERN CALIFORNIA.** **C. T. Collins.** Department of Biological Sciences, California State University, Long Beach, CA 90840.

88 2:00 **POPULATION STATUS OF THE CALIFORNIA LEAST TERN.** **K.M. Keane.** Keane Biological Consulting, 2892 N. Bellflower Blvd., Suite 480, Long Beach, CA 90815.

89 2:20 **LEAST BELL'S VIREO IN THE SANTA ANA RIVER WATERSHED.** **R. Zembal.** Orange County Water District, 10500 Ellis Avenue, Fountain Valley, CA 92708.

90 2:40 **POPULATION STATUS OF THE WESTERN GULL-BILLED TERN (*STERNA NILOTICA VANROSSEMI*) IN NORTH AMERICA.** **K. C. Molina.** Ornithology, Natural History Museum of Los Angeles County, 900 Exposition Blvd., Los Angeles, CA 90007.

3:00–3:20 **BREAK**

91 3:20 **POPULATION STATUS OF LIGHT-FOOTED CLAPPER RAIL.** **R. Zembal,** S.M. Hoffman, and J. Konecny. Department of Biological Sciences, CA State University, Long Beach 90840.

92 3:40 **THE STATUS OF WESTERN SNOWY PLOVERS IN COASTAL SOUTHERN CALIFORNIA.** **Kevin B. Clark.** U.S. Fish and Wildlife Service, Carlsbad, CA 92009.

93 E 4:00 **DIETARY RESPONSE OF THE ELEGANT TERN (*STERNA ELEGANS*) TO CHANGING OCEAN CONDITIONS AND PREY POPULATIONS IN SOUTHERN CALIFORNIA.** **K. L. Connell** and M. H. Horn. California State University, Fullerton, Department of Biological Science, Fullerton, CA 92834.

Saturday, May 21, 2005
Location: Hilton Business Center, Rm. 109

Session: Contributed Papers

Chair: Jon Baskin

94 E 8:40 **GAS EXCHANGE RESPONSES TO PULSE RAIN EVENTS BY A NATIVE HAWAIIAN DRY FOREST VINE AND THE EFFECT OF INTERACTION WITH NON-NATIVE GRASSES.** **P.A. Koenig** and D.R. Sandquist. Department of Biological Science, California State University, Fullerton, CA 92831.

95 E 9:00 **BORN AND RAISED IN SOUTHERN CALIFORNIA: DEVELOPMENTAL EVOLUTION AND CRYPTIC SPECIATION IN THE SEA SLUG GENUS *ALDERIA*.** **R.A. Ellingson** and P.J. Krug. California State University Los Angeles, Department of Biological Sciences, Los Angeles, CA 90032.

96 E 9:20 **SHALLOW SURF RIDERS: SMALL-SCALE LARVAL DISTRIBUTION IN ESTUARINE WATERS.** **D.A. Willette** and P.J. Krug. California State University, Los Angeles, Department of Biological Sciences, Los Angeles, CA 90032.

97 9:40 **RAPID ASSESSMENT OF TERRESTRIAL AND MARINE HABITATS USING TWO NOVEL METHODS FOR ESTIMATING THE DENSITIES AND DISTRIBUTIONS OF ORGANISMS.** **G.K. Nishiyama** and C.A. Kay. College of the Canyons, Department of Biology, Santa Clarita, CA 91355.

98 10:00 **ON SOUTHERN CALIFORNIA ABYSSAL ECHINODERMS.** **K.D. Trego.** Nautilus Oceanic Institute, La Jolla, CA 92037.

99 10:20 **THE DEEP SEA HOLOTHURIAN SCOTOPLANES GLOBOSA OFF SOUTHERN CALIFORNIA.** **K.D. Trego.** Nautilus Oceanic Institute, La Jolla, CA 92037.

Saturday, May 21, 2005
Location: Hilton Business Center, Rm. 100

Session: SETAC Plenary Session; "New Frontiers in Environmental Chemistry"

Chair: Lan Wiborg, City of San Diego

100 8:40 **TOOLS FOR TRACKING THE FATE OF WASTEWATER-DERIVED CONTAMINANTS IN EFFLUENT-DOMINATED WATERS.** **David L. Sedlak.** University of California, Berkeley, CA.

101 9:20 **CONTAMINANT FATE AND SOURCE TRACKING USING CHIRAL AND STABLE ISOTOPE ANALYSIS.** **Kieth Maruya, K.A.*** and Peng, J., SCCWRP, Westminster, CA; Zeng, E.Y., Chinese Academy of Sciences, Guangzhou, China.

102 10:00 **CHEMICAL METHODS FOR MEASURING BIOAVAILABILITY.** **Jay Gan.** Department of Environmental Science, University of California, Riverside.

10:40–11:00 **BREAK**

11:00–12:00 **Plenary Talk: Dr. James Powell: The Grand Canyon: Solving Earth's Grandest Puzzle.**

12:00–1:20 **LUNCH BREAK**

Saturday, May 21, 2005
Location: Hilton Business Center, Rm. 100

Session: Marine Pollution: Contaminants, Bioaccumulation and Effects on Marine Organisms (Jointly sponsored by SCAS and SETAC)

Chair: Jim Allen and Ken Schiff, (SCCWRP)

103 1:20 **WATER QUALITY ON SWIMMING BEACHES: NEW DIRECTIONS FOR THE EUROPEAN UNION.** **A. Staines.** Urban Water Technology Centre, University of Abertay Dundee, Bell St, Dundee, DD1 1HG, Scotland, United Kingdom.

104 1:40 **CONTAMINANT TRENDS IN THE SOUTHERN CALIFORNIA BIGHT: A MUSSEL WATCH UPDATE.** **A. J. Mearns** and G. Lauenstein. National Ocean Service, National Oceanic and Atmospheric Administration, Seattle, WA and Silver Spring, MD.

105 2:00 **A COMPARISON OF TRACE METAL CONCENTRATIONS IN DEEP OFFSHORE AND NEARSHORE SEAWATER FROM SOUTHERN CALIFORNIA.** **Richard Gossett.** CRG Marine Laboratories, 2020 Del Amo Blvd, Torrance, CA 90501.

106 2:20 **HEAVY METAL ACCUMULATION IN SEA TURTLES FROM THE BAJA CALIFORNIA PENINSULA, MEXICO.** **S.C. Gardner,** S.L. Fitzgerald, B. Acosta Vargas L. Méndez Rodríguez. Centro de Investigaciones Biológicas del Noroeste, S.C., La Paz, Baja California Sur, Mexico.

107 2:40 **PROBING METAL-LIGAND INTERACTIONS USING STABLE ISOTOPICALLY LABELED PROTEINS AND DIRECTLY COUPLED HPLC-ICP-MS.** **A.Z. Mason**, T.M. Potter, J. Webster, and R.F. Meraz. Department of Biological Sciences and Institute for Integrated Research in Materials, Environments and Society, California State University, Long Beach, 90840, USA.

3:00 **BREAK**

108 3:20 **STRATIFYING BAY AND ESTUARY HABITATS OF THE WEST COAST OF THE CONTIGUOUS USA: A STEP TOWARD REGIONAL INDICATORS OF BENTHIC COMMUNITY CONDITION.** **J.A. Ranasinghe**[1], K.I. Welch[2], P.N. Slattery[3], D.E. Montagne[4], D.D. Huff[5], H. Lee, II[6], J.L. Hyland[7], B. Thompson[8], S.B. Weisberg[1], J.M. Oakden[3]. [1]SCCWRP, Westminster, CA; [2]Washington State Department of Ecology, Olympia, WA; [3]Moss Landing Marine Laboratory, Moss Landing, CA; [4]County Sanitation Districts of Los Angeles County, Whittier, CA; [5]Oregon Dept. of Environmental Quality, Portland, OR; [6]US EPA, Western Ecology Division, Newport, OR; [7]NOAA, NOS, Charleston, SC; [8]San Francisco Estuary Institute, Oakland, CA.

110 3:40 **DISRUPTION OF THE STRESS RESPONSE ENDOCRINE SYSTEM IN MARINE FISHES IN THE SOUTHERN CALIFORNIA BIGHT.** **Kevin M. Kelley**, Jesus A. Reyes, Kathy Sak, Shari Smolko, and Jeffery L. Armstrong*. Department of Biological Sciences, California State University, Long Beach, Long Beach, CA 90840; *Orange County Sanitation District (OCSD), Fountain Valley, CA, 92708.

111 4:00 **GROWTH ENDOCRINE DISRUPTION IN SOUTHERN CALIFORNIA MARINE FLATFISH.** **Jesus A. Reyes** and Kevin M. Kelley. Department of Biological Sciences, California State University, Long Beach, Long Beach, CA 90840.

109 F 4:20 **INFESTATION OF PARASITIC COPEPODS AND THE POTENTIAL OF STRESS ON HOST FISHES.** **Julianne E. Kalman.** University of California Los Angeles, Department of Ecology and Evolutionary Biology, Los Angeles, CA 90095 and Orange County Sanitation District, Environmental Assessment Division, Fountain Valley, CA 92708.

112 4:40 **BIOACCUMULATION OF CONTAMINANTS IN RECREATIONAL AND FORAGE FISHES IN NEWPORT BAY, CALIFORNIA IN 2000–2002.** **M. J. Allen**[1], D. W. Diehl[1], and E. Y. Zeng[2]. [1]Southern California Coastal Water Research Project, Westminster, CA 92683; [2]State Key Laboratory of Organic Geochemistry, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, P.O. Box 1131, Guangzhou 51064, China.

Saturday, May 21, 2005
Location: Business Center, Rm. 109

Session: Environmental Toxicology and Chemistry (SETAC)

Chair: Jeff Armstrong, Orange County Sanitation District

113 1:20 **OXIDATION OF SELENOMETHIONINE BY FLAVIN-CONTAINING MONOOXYGENASES (FMOS).** **D. Shi** and D. Schlenk. University of California, Riverside, Riverside, CA 92521.

114 1:40 **ENANTIOSELECTIVITY IN PYRETHROID DEGRADATION IN SOIL.** **S. Qin**, M. G. Nillos, and J. Gan. University of California, Riverside, Riverside, CA 92521.

115 M 2:00 **ENANTIOMERIC SULFOXIDATION OF THE ORGANOPHOSPHATE PESTICIDE FENTHION IN FISH.** **O. Bawardi**[1], B. Furnes, J. Rimoldi[2], D. Schlenk[1]. [1] University of California Riverside, Riverside, CA 92521; [2]The University of Mississippi, University, MS 38677.

116 2:20 **LINKING BIOMARKER RESPONSES AND PHYSIOLOGICAL STRESS TO GROWTH IMPAIRMENT OF CADMIUM-EXPOSED LARVAL TOPSMELT.** **W. Rose**[1], R. Nisbet[2], P. Green[3], S. Norris[4], T. Fan[4,5], E. Smith[1], G. Cherr[1], and S. Anderson[1]. [1]Bodega Marine Laboratory, University of California Davis, Bodega Bay, CA; [2]Ecology, Evolution, and Marine Biology, University of California Santa Barbara, Santa Barbara, CA; [3]Civil & Environmental Engineering, [4]Land, Air, and Water Resources, University of California Davis, Davis, CA; [5]Chemistry, University of Louisville, Louisville, KY.

117 2:40 **ARTHROGRYPOSIS FOLLOWING ACRYLAMIDE EXPOSURE. J.G. Dahlgren**[1], R.T. Schmidt[2], and H.S. Takhar[2]. [1]UCLA School of Medicine, Los Angeles, CA; [2]James Dahlgren Medical, Los Angeles, CA.

3:00 **BREAK**

118 M 3:20 **EXPRESSION AND CHARACTERIZATION OF CHANNEL CATFISH CYP 2X1. S. Mosadeghi**, B. Furnes, C. Wong, D. Schlenk. University of California, Riverside, Riverside, CA 92521.

119 3:40 **IDENTIFYING ALUM AS A TOXICANT IN WHOLE EFFLUENT TOXICITY TESTS. K. Rinald**, P. J. Markle, C. Barton, E.X. DeHollan, and J.P. Bottomley. County Sanitation Districts of Los Angeles, Whittier, CA 90601.

Saturday, May 21, 2005
Location: Hilton Business Center, Rm. 118

Session: Application of Freshwater Bioassessments in Southern California (Sponsored by SETAC)

Chair: Scott Johnson, ABC Labs. Ventura

120 1:40 **DEVELOPMENT OF A MACROINVERTEBRATE IBI FOR SOUTHERN COASTAL CALIFORNIA AND USE OF PROBABILISTIC SAMPLING FOR REGIONAL STREAM CONDITION ASSESSMENTS.** P. R. Ode, *A. C. Rehn** and J. T. May. California Department of Fish and Game, Rancho Cordova, CA.

121 2:20 **ALGAE-NUTRIENT RELATIONSHIPS AND TMDL DEVELOPMENT IN MALIBU CREEK, CALIFORNIA. S. L. Luce***[1], R.F. Ambrose[2] and M.A. Abramson[1]. [1]Heal the Bay, Santa Monica, California; [2]University of California, Los Angeles, California.

3:00 **BREAK**

122 3:20 **FRESHWATER STREAM INVERTEBRATES: RESPONSE TO PHYSICAL HABITAT ALTERATION AND WATER QUALITY IMPAIRMENT IN SOUTHERN CALIFORNIA. B.H. Isham***. B.T. Ferguson Weston Solutions, Inc., Carlsbad, CA.

123 4:00 **THE APPLICATION OF STREAM BIOASSESSMENTS IN POINT AND NON-POINT SOURCE REGULATORY PROGRAMS. S. Johnson.**

124 4:20 **USE OF *IN SITU* HATCHBOX STUDIES TO EVALUATE WATER QUALITY EFFECTS. H. Bailey**[1], B. Chalmers[2], and J. Elphick[1]. [1]Nautilus Environmental, San Diego, California; [2]Myra Falls Mine, Campbell River, British Columbia.

Saturday, May 21, 2005
Location: Hilton Business Center, Rm. 300a

Session: Research Training Program: Session I

Chair: Martha Schwartz

125 9:40 **THE EFFECTS OF SEQUENCING: MEMORY ITEMS VS. PERCEPTUAL LEARNING. L. Calfas**[1] and P. Kellman[2]. Marlborough School[1], Los Angeles, CA, 90004; UCLA[2], Department of Psychology, Los Angeles, CA, 90095.

126 10:00 **CREB-MUTANT PERFORMANCE IN A NOVEL LEARNING TASK. D. Chin.** Alhambra High School, Alhambra, CA. *Mentor:* Dr. Amelia Russo-Neustadt.

127 10:20 **OPERATIONAL EFFECTS OF ALTERED ABIOTIC FACTORS ON NITRIFYING BACTERIA: YEAR 2. Sanjit Datta.** Palos Verdes Peninsula High School and Cabrillo Marine Aquarium, San Pedro, CA 90731.

10:40 **BREAK**

11:00 **Plenary Talk: Dr. James Powell: The Grand Canyon: Solving Earth's Grandest Puzzle.**

12:00–1:20 **LUNCH BREAK**

Session: Research Training Program: Session I (Continued)

Chair: Richard Schwartz

128 1:20 **STRAIN RELATEDNESS OF *CANDIDA* IN HUMANS: A URINARY PATHOGEN OR COLONIZER? (PHASE 2). Joon-Bok Lee.** California Academy of Math and Science, and Division of Infectious Diseases, Los Angeles County Harbor-UCLA Medical Center, 1000 W. Carson Street, Torrance, California 90502.

129 1:40 **MAINTAINING CORRECT BALANCE: SPATIAL CODING AND ITS DEPENDENCE ON NATURAL STIMULI. D.E. Lluncor.** Research Training Program, Palos Verdes Peninsula High School, Rolling Hills Estates, CA, 90274.

130 2:00 **EFFECTS OF ATMOSPHERIC CARBON DIOXIDE ON THE NITROGEN FIXATION CAPABILITIES OF *TRICHODESMIUM*. S.F. Ong,** J. Sohm, and D.G. Capone. California Academy of Mathematics and Science, Carson, CA 90747; Wrigley Institute for Environmental Science, University of Southern California, Los Angeles, CA 90098.

131 2:20 **USING THE INHIBITORY EFFECTS OF ATP ANALOGS TO REGULATE MRNA PROCESSING: YEAR II. Carol Y. Suh.** Palos Verdes Peninsula High School, and University of California, Los Angeles, Department of Chemistry and Biochemistry, Los Angeles, CA, 90095.

132 2:40 **STUDY OF THE EFFECTS OF *NEURAL LAZARILLO* OVEREXPRESSION IN TRANSGENIC *DROSOPHILA MELANOGASTER*. Derek Tam.** Alhambra High School. *Mentor:* Julien Muffat (laboratory of Pr. Seymour Benzer).

3:00 **BREAK**

133 3:20 **3D MODEL OF ALGORITHM PERFORMANCE ON THE 3-SATISFIABILITY PROBLEM. Timothy Uy,** California Academy of Math and Science; and Dennis Kibler, Department of Computer Science, University of California: Irvine, Irvine, California 92697-3425.

134 3:40 **PROSTATE CANCER PREVENTION BY POLYPHENOLIC COMPOUNDS IN GREEN TEA. Elysia Chin.** Alhambra High School and University of Southern California, Keck School of Medicine, Los Angeles, CA, 90033.

4:00 **Presentation by students who went to National AAJAS Meeting and student Intel Science Contestants.**

Saturday, May 21, 2005
Location: Hilton Business Center, Rm. 300b

Session: Research Training Program: Session II

Chair: Kathy Phalen

135 9:40 **IMPORTANCE OF DROSOPHILA EIF4E-BINDING PROTEINS IN LIFESPAN REGULATION. Tony Au Lu.** Alhambra High School. *Mentor:* Brian M. Zid; *Teacher:* Mr. Duane Nichols.

136 10:00 **MOTHER'S CHARACTRISTICS AND HER CHILD FEEDING HABITS. April Stephenson** and Maivy Nguyen. Dr. Fary Cachelin, California State University Los Angeles, Department of Psychology, Los Angeles, CA, 90041.

137 10:20 **ROLES OF AUXOTROPHIC MARKERS IN *CANDIDA ALBICANS* VIRULENCE. D. Im,** California Academy of Math and Science; and H. Park, Division of Infectious Diseases, Department of Medicine, Los Angeles Biomedical Research Institute at Harbor-UCLA Medical Center, Torrance, CA 90502.

10:40 **BREAK**

11:00 **Plenary Talk: Dr. James Powell: The Grand Canyon: Solving Earth's Grandest Puzzle.**

12:00–1:20 **LUNCH BREAK**

Session: Research Training Program: Session II (Continued)

Chair: Harry Takahashi

138 1:20 **PREDICTING MATERIAL FAILURE: CORRELATION BETWEEN DEFORMATION LUMINESCENCE AND HYSTERESIS.** **Geoffrey H. Woo.** UCLA, Department of Physics and Astronomy, Los Angeles, CA 90095-547.

139 1:40 **CHANGES IN DENSITIES OF FECAL INDICATOR BACTERIA (FIB) OVER DIFFERING TIDAL FLOWS IN THE BALLONA WETLANDS, LOS ANGELES.** **S. Yanamadala**[1] and John H. Dorsey[2]. [1]Chadwick High School, 26800 S. Academy Drive, Palos Verdes Peninsula, CA, 90274; [2]Loyola Marymount University, Department of Natural Sciences, Los Angeles, CA, 90045.

140 2:00 **POLYPHENOL EFFECT ON SUSCEPTIBILITY OF OXIDIZED β-AMYLOID PEPTIDE TO INSULIN DEGRADING ENZYME.** **J. Young.** Alhambra High School and USC Keck School of Medicine, School of Pharmacy, Department of Pharmaceutical Science, Los Angeles, CA, 90089.

141 2:20 **EFFECTS OF SALINITY CONCENTRATION ON RATES OF POLYP CLONING, GROWTH, AND STROBILATION IN THE *AURELIA LABIATA* (CNIDARIA, SCYPHOZOA).** **Julie A. Guerin.** Cabrillo Marine Aquarium, San Pedro, CA 90731 (Palos Verdes Peninsula High School, Rolling Hills Estates, CA 90274).

142 2:40 **MECHANISM OF FAILED ALVEOLARIZATION FOLLOWING IN UTERO NICOTINE EXPOSURE.** **Kabre, Sanyl.** Hawthorne High School, Hawthorne, CA.

3:00 **BREAK**

143 3:20 **SEASONAL CHANGES AND YEAR-TO-YEAR VARIABILITY OF THE NORTHERN WATER ICE CAP FROM MARS GLOBAL SURVEYOR; MARS ORBITER CAMERA AND THERMAL EMISSION SPECTROMETER.** **Katherine Lu** and **Angela Guo.** Alhambra High School.

144 3:40 **CONDITIONAL KNOCKOUT OF LMO4.** **Jerry Kwong,** Yu Zhenquan, and Bogi Andersen. University High School and University of California Irvine, School of Medicine.

4:00 **Presentation by students who went to National AAJAS Meeting and student Intel Science Contestants.**

ABSTRACTS

1 SOUTHERN CALIFORNIA WETLAND RECOVERY PROJECT

Mary Small. State Coastal Conservancy

The Southern California Wetland Recovery Project (WRP) began in 1998 with the execution of an agreement that committed 17 state and federal agencies to develop and implement a regional plan for acquisition and restoration to increase the quantity and quality of the region's wetlands. The geographic scope of the WRP includes coastal wetlands and watersheds from Point Conception south to the U.S. Mexico border. The long-term objective of the WRP is to reestablish a mosaic of fully functioning wetlands systems, with a diversity of habitat types and connections to upland communities, which preserves and recovers self-sustaining populations of species. In the Regional Strategy, the WRP identified the following regional goals:

1. Preserve and restore coastal wetland ecosystems.
2. Preserve and restore stream corridors and wetland ecosystems in coastal watersheds.
3. Recover native habitat and species diversity.
4. Integrate wetlands recovery with other public objectives.
5. Promote education and compatible access related to coastal wetlands and watersheds.
6. Advance the science of wetlands restoration and management in Southern California.

To achieve these goals, the WRP has developed a broad-based partnership that includes 17 state and federal agencies working in concert with scientists, local governments, environmental organizations and business leaders. The WRP helps implement priority acquisition and restoration projects. In addition, the WRP awards small grants for projects that involve the public in hands-on restoration activities. The Science Advisory Panel of the WRP is developing a long-term, region-wide monitoring program for southern California wetlands and riparian areas.

2 BALLONA WETLANDS–COMMUNITY BASED RESTORATION PLANNING

Mary Small. State Coastal Conservancy

After more than thirty years of contentious land use dispute, last spring the State of California became the owner of more than 600 acres of the former Ballona Wetlands in Los Angeles. The site is near the mouth of Ballona Creek and is considered to be one of the best remaining opportunities for landscape-scale wetland restoration in Los Angeles County. However, there are significant constraints that may limit restoration activities, including existing infrastructure and easements. The restoration plan will seek to restore and enhance salt water influenced wetland habitat while also providing for wildlife-oriented public access and recreation opportunities where compatible. In September 2004, the State Coastal Conservancy, the California Department of Fish and Game and the State Lands Commission began a community based restoration planning process to develop a plan for interim site management and long-term enhancement of the property. The agencies have structured a planning process incorporates scientific input and is also transparent to all of the community's stakeholders. Restoration planning is expected to take up to three years.

3 ORMOND BEACH: RESTORATION OF HISTORIC WETLANDS

Peter Brand. State Coastal Conservancy

Ormond Beach is considered by wetland experts to be the most important wetland restoration opportunity in southern California. Prior to development, the coast of Ventura was a vast complex of dunes, lakes, lagoons, and salt and freshwater marshes. From the Santa Clara River estuary to the beginning of Mugu Lagoon, it appears from historic maps that there were seven lagoons. Most have either disappeared, been severely degraded, or been converted to marinas or ports. Nevertheless, this is the only place in southern California where it is still possible to restore close to the historic extent of wetlands.

The wetlands at Ormond Beach once covered approximately 1,000 acres; approximately 250 acres remain. The Coastal Conservancy has acquired 265 acres and expects to close soon on the acquisition of another 276 acres. The Conservancy has begun a restoration feasibility study for Ormond Beach and adjoining wetlands that would show how this area could be restored and linked hydrologically and as an ecosystem. A critical mass of 750 acres of restored wetlands and associated habitat at Ormond Beach is expected to create a self-sustaining biological system and enough tidal prism and flushing action to maintain health and hydrologic function. Anticipated restoration at Ormond Beach would include modifications of the site hydrology to restore tidal action and bring back freshwater flows that had formerly drained across the Oxnard Plain to the coastal wetlands. When integrated with the adjoining 900 acres of freshwater wetlands and the 1,500 acres at Mugu Lagoon, this could be the largest coastal wetland in southern California, spanning nine miles of the coast from Point Hueneme to Point Mugu.

4 THE MALIBU LAGOON ENHANCEMENT PROJECT

C.S. Shuman. Heal the Bay, 3220 Nebraska Ave., Santa Monica, CA 90404

Malibu Lagoon is a 31 acre shallow water estuarine system that has been degraded by habitat encroachment and poor water quality. Previous restoration efforts led by California State Parks in the 1980's successfully restored some wetland habitat but did not adequately restore the natural structure and function to the estuarine ecosystem. The current configuration does not allow for adequate water circulation that, in addition to existing water quality impairments for nutrients and bacteria, promotes degraded water quality and habitat conditions. To address this situation, the California State Coastal Conservancy, in cooperation with California State Parks, has initiated the preparation of a restoration and enhancement plan for Malibu Lagoon.

This project identified and evaluated design options to restore the natural structure and function to the lagoon ecosystem, while minimizing impacts to existing brackish marsh habitat. All restoration options were designed to maintain existing access and increase opportunities for interpretation, education and stewardship for the 1.5 million annual visitors to the site. A collaborative approach directed by input from the Lagoon Technical Advisory Committee and the Lagoon Restoration Working Group was used to identify the restoration alternative that is expected to most readily achieve the biological and social goals of the project while introducing the least amount of impact to the existing lagoon ecosystem. A phased restoration implementation and long-term adaptive management approach will be implemented to maximize the ecosystem benefits of this restoration process.

5 ECOSYSTEM RESTORATION AT TIJUANA ESTUARY, CALIFORNIA

Chris Nordby. Tierra Environmental Services, 9915 Businesspark Avenue, Suite C, San Diego, CA 92131

Tijuana Estuary is a complex ecosystem that has been highly modified by human land use practices. The estuary is located entirely within San Diego County, California, although three fourths of its watershed is in Mexico. Unregulated land development within the Mexican portions of the watershed has resulted in an increased sediment supply throughout the watershed. As a result, sensitive wetland habitats have been buried, converting once productive salt marsh to ruderal upland habitats.

Management of the estuary is entrusted to a multi-agency Management Authority, which recognized the consequences of uncontrolled sediment deposition on the system. The Management Authority recommended two broad goals to reverse the trend of wetland loss: 1) Control sedimentation within the watershed, and 2) Restore areas degraded by sedimentation.

In the 1980's, the California State Coastal Conservancy initiated plans for controlling sediment and restoring the estuary. Working with Southwest Wetlands Interpretive Association, a non-profit organization, and Tierra Environmental Services the Conservancy has accomplished the following milestones:

- Constructed a 2.5-acre channel connecting formerly landlocked portions of the estuary to reduce sedimentation in backwater areas;
- Constructed a 20-acre Model Marsh project to restore intertidal salt marsh in an area subjected to disturbance;
- Constructed a series of managed sediment basins to control areas of high sediment deposition;
- Funded a study to restore approximate 250 acres of degraded habitat in the southern portion of the estuary.

These efforts have contributed to the reversal of human disturbance of the wetland; however, sediment continues to present management challenges.

6 RESTORING WETLANDS ON A GRASSROOTS LEVEL–NON-PROFITS AND WETLAND RESTORATION

D. Gibson. San Elijo Lagoon Conservancy Executive Director/Principal Scientist, Encinitas, CA 92023

The San Elijo Lagoon Conservancy (SELC) is a non-profit organization that began in 1987 out of concerns of development surrounding the San Elijo Lagoon Reserve. The organization built a membership of over 2,000 members and began educating its members. In 1995, the SELC hired an executive director with a scientific background and began conducting research and restoration projects. Currently, SELC maintains over 20 years of baseline data for water quality, fish, invertebrates, and bird data. SELC has raised over $10 million for projects and now employs 5 full time employees. SELC has written the San Elijo Lagoon Action Plan, which led to the baseline biological report for the full restoration of the lagoon for the Army Corps Of Engineers. This project encompasses moving infrastructure and removing past impacts to the system that have muted the tidal prism and changed habitat. SELC has also conducted studies that analyzed the sediment throughout the lagoon and are in the process of creating an Action Plan for the Escondido Creek Watershed, which drains into the San Elijo Lagoon. This past year we began one of the largest invasive species removal projects that have been funded by the State. The $4 million project will remove over 300 acres of invasive species from the riparian corridors of the Carlsbad Hydrologic Unit, of which the Escondido Creek watershed is a part. The SELC has been very successful in both restoring and enhancing habitat, as well as serving as a critical partner for federal, state and local government.

7 THE JOURNEY FROM WETLANDS TO OIL FIELD AND BACK

Jim Trout. State Lands Commission

The presentation will discuss the conversion of historic natural wetlands to commercial and oil field development and back to wetlands, all in a century.

Bolsa Chica lowlands in Huntington Beach, Orange County, were, in part, tide and submerged lands at the time of California statehood in 1850. A natural opening to the ocean existed near the current location of Warner Ave. and Pacific Coast Highway. This opening closed up after the lowlands were converted to farming operations and later into a duck-hunting club. In the 1950's oil was discovered the area and development of that resource was begun. The duck club was phased out while dikes, roads and oil drilling production pads were constructed in the lowlands. Oil continues to be produced from the lands today.

In the 1960's and '70's, attempts were made to develop the lowlands for residential housing. The upper area was built up into residential subdivisions. The lowland ownership was split into surface and mineral estates and efforts made to develop the surface for housing. Development in the lowlands was resisted by a number of environmental groups throughout 1970's and 1980's. A number of plans were considered but none were permitted.

In 1995, the ports of Long Beach and Los Angeles needed to mitigate for harbor fill required to expand their deep-water multi-modal marine terminals. Agreement was reached with state and federal agencies whereby the ports would pay for mitigation credits, the funds to be used to acquire and restore the Bolsa Chica lowlands. In 1997 the ports and eight state and federal agencies implementing the restoration effort signed an agreement.

The Agreement would fund acquisition 880 acres of the Bolsa Chica Lowlands (other than the subsurface mineral interests), purchase of the remaining production on 550 of those acres, abandonment of some oil and gas production facilities, and restoration of two-thirds of the area as wetlands, construction of a new inlet to the ocean with a new bridge over the inlet at Pacific Coast Highway. A full tidal regime would be established for 367 acres. Some 178 acres would have a muted tidal range, plus there will be nesting islands created for threatened and endangered birds as well as other amenities.

A number of public town meetings were conducted and an environmental impact document prepared, a restoration plan adopted and final plans and specifications completed. Proposals were solicited from contractors during June and July of 2004, contractor selection made during August. Work began in the field November 1, 2004. A formal groundbreaking was held on October 6 at the site. Completion is scheduled for the end of July 2006.

8 ENGINEERING OF THE BOLSA CHICA WETLANDS RESTORATION PROJECT

Chris Webb, Michael McCarthy, Moffatt & Nichol; Jack Fancher, U.S. Fish and Wildlife Service; and Keith Merkel, Merkel & Associates

The Bolsa Chica project is the largest salt marsh restoration project on the west coast, and represents the largest salt marsh restoration project by the USFWS. Eight government agencies forming the Steering Committee lead the effort, and a consulting team of five local firms performed the engineering for construction. Construction started last year and is rapidly progressing.

The project has been active for nearly 30 years. It consists of restoring the former Bolsa Chica wetland at the historic mouth of the Santa Ana River (prior to it shifting south to its existing position). The site is approximately 1,000 acres in size and lies immediately inland from Pacific Coast Highway just north of Huntington Beach. It represents a critical link along the Pacific Flyway for use by endangered birds such as the Western snowy plover and California least tern.

The project includes installation of a new ocean entrance stabilized by jetties that will connect to a deepwater basin will be dredged on approximately 365 acres contained by dikes, and will feed peripheral muted tidal areas over 200 acres through culverts in the dikes. New subtidal areas are being created for fish, mudflats and vegetated intertidal areas are being created for invertebrates and birds, and three new large nesting islands are being created for snowy plovers and least terns. Construction affects existing habitats, so other existing sensitive areas are being preserved and enhanced to offset effects for net benefits. Dredging will create a large mound of sandy fill in the shallow ocean off of the inlet, and beach nourishment along Bolsa Chica State Beach. New bridges are being constructed at the future inlet on Pacific Coast Highway and within the oil field. A significant groundwater control device is being installed along the project boundary nearest adjacent homes. Construction will last until 2007.

Challenges during construction include the extremely wet winter of 2004–05, sensitive species nesting in spring seasons of 2005 and 2006, and existing constraints related to oil field operation, use of the state beach, site clean-up activities, and other factors. These issues are addressed and related in the presentation.

9 USING SPATIALLY-EXPLICIT MODELS TO PREDICT EELGRASS DISTRIBUTION FOR RESOURCE MANAGEMENT AND RESTORATION

Robert Mooney. Merkel and Associates Inc.

A model that predicts potentially suitable eelgrass habitats was developed using eelgrass habitat requirements. The predictive model is a spatial, numerically-based, static habitat suitability index (HSI) model focusing on physical parameters that contribute to the observed distribution patterns of eelgrass. Data on eelgrass distribution, bathymetry, maximum orbital velocity, residence time, salinity, and hours of light saturation were combined to create the predictive model. Each spatially explicit theme was used to depict the range of environmental parameters affecting eelgrass distribution. The modeling framework used for the predictive eelgrass model was the Ecological Limits, Viability, and Sustainability (ELVS) model, which was originally developed by Merkel & Associates in order to make eelgrass habitat suitability predictions from bathymetric, hydrodynamic, and atmospheric data. This predictive model of suitable eelgrass habitat will provide resource managers improved capabilities to detect and track changes in eelgrass resources.

10 EVALUATING THE SUCCESS OF WETLAND MITIGATION IN LOS ANGELES AND VENTURA COUNTIES: ASSESSING PERMIT COMPLIANCE AND WETLAND CONDITION

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The Clean Water Act provides the most important protection of wetlands in the United States; an important element of this protection is the requirement for compensatory mitigation, by which wetland resources are created or restored to compensate for losses due to impacts to natural wetlands. In this study, we assessed 50 compensatory mitigation projects required by the Los Angeles Regional Water Quality Control Board in Los Angeles and Ventura Counties through an extensive review of permit files and field monitoring to map the area of the mitigation sites and assess (1) compliance with permit conditions and (2) habitat condition. Twenty mitigation projects had multiple locations, yielding 79 individual mitigation site evaluations. A majority of the sites (69%) complied with all of their (assessable) permit conditions. Overall, the mitigation projects met their acreage requirements; omitting projects with undetermined boundaries, the total acreage lost in our assessment permits was 56 ha, the acreage required was 80 ha, and the acreage we measured was 91 ha. However, many of the mitigation sites did not have optimal wetland condition. Using a modified version of the California Rapid Assessment Methodology (CRAM), which assesses 15 different metrics in four main categories, we determined that 29% of the sites were in marginal to poor condition, 67% were of sub-optimal condition, and only three sites (4%) were in optimal condition. We conclude that the goal of no net loss of wetland functions and services has not been achieved in the Los Angeles region.

11 DEVELOPMENT OF AN INTEGRATED REGIONAL ASSESSMENT PROGRAM FOR SOUTHERN CALIFORNIA WETLANDS

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Historic and continued loss of wetland and riparian systems is one of southern California's most pressing natural resource management issues. In 1997, the southern California Wetlands Recovery Project (WRP) was formed to increase regional coordination of wetland preservation, restoration, and management among 17 state and federal agencies. As of September 2003, the WRP had spent of $61.8 million on 34 wetland acquisition, restoration and enhancement projects. However, the WRP currently lacks the ability to assess the progress of regional wetland ecosystem recovery, relative to continued wetland loss and degradation. To address this shortcoming, the WRP is developing an integrated wetlands regional assessment program (IWRAP) that will assess status and trends of wetland condition, measure recovery progress, evaluate the effect of anthropogenic stressors, and evaluate the effect of wetland management actions on the regional wetland ecosystem. The IWRAP will encompass all tidal and non-tidal wetland classes within southern California's coastal watersheds, and is based on a three-tiered assessment design: *Level I* assessment evaluates extent and distribution of wetlands and associated resources. *Level II* assessment evaluates wetland condition and stressors on a regional scale. *Level III* assessment addresses detailed management questions of stressors and condition on a site-specific scale. Key elements of the IWRAP are that 1) assessment questions are directly linked to management questions; 2) the intensity of a specific assessment is commensurate to the importance of the management question being addressed; 3) assessments are adaptive, and choices regarding special studies and other intensification efforts are informed by the results of coarser monitoring; 4) assessments are cost-effective, yet scientifically rigorous; and 5) project specific performance monitoring is consistent with ambient assessment. The estuarine component of the IWRAP includes 13 assessment questions that will evaluate wetland condition relative to areal extent, hydrology, sediments, contaminants, biota, and landscape context. When fully implemented, the IWRAP will streamline reporting of monitoring data, making them more accessible for routine scientific evaluation of restoration and management techniques, and will help to evaluate recovery priorities and ensure that WRP use of public funds has a lasting regional impact.

12 MONITORING PLAN FOR THE SAN DIEGUITO LAGOON RESTORATION PROJECT

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The San Dieguito Wetlands Restoration Project is required of Southern California Edison by the California Coastal Commission as mitigation for the operation of the San Onofre Nuclear Generating Station (SONGS). The restoration will consist of the creation of 115 acres of tidal wetlands with an additional 35 acres credit given for a commitment to maintain the lagoon inlet in an open condition in perpetuity. Habitats to be created in the restoration include subtidal, intertidal mudflat, coastal salt marsh, and transitional wetland. The success of the restoration will be evaluated using performance standards outlined in the Coastal Development Permit for the operation of SONGS. The restoration project is required to meet both physical (e.g., topography, water quality) and biological (e.g., fish, invertebrates, birds, vegetation) performance standards. A monitoring plan has been developed to guide the post-restoration monitoring work that will measure the success of the restoration project in achieving the performance standards. This plan includes the physical and biological performance standards on which the success of the restoration will be evaluated and recommended sampling methods for collecting the information needed to evaluate each standard. Key elements of monitoring program include independent monitoring and the use of reference sites in evaluating wetland performance.

13 QUANTIFYING THE PERFORMANCE OF DIFFERENT REEF DESIGNS ON KELP BED FISH AND BENTHIC COMMUNITY DEVELOPMENT AT THE SAN CLEMENTE EXPERIMENTAL ARTIFICIAL REEF

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Determining the success of an artificial reef as a tool for mitigating human-induced losses to fish populations and benthic communities requires explicit standards for assessing the performance of the reef and a robust monitoring program that is designed to collect the information necessary to evaluate those standards. The effects of material type (recycled concrete vs. quarry rock) and bottom coverage (30 to 90%) on fish and benthic community development were evaluated over a five year period in a large scale (~ 9 ha) artificial reef experiment off of San Clemente. Here we describe: 1) the biological performance standards established for kelp bed fishes and benthic communities on an artificial reef that will be built to compensate for the loss of kelp bed habitat caused by the operation of a coastal power plant in, San Onofre Nuclear Generating Station, Units 2&3 (SONGS); 2) an assessment of different methods of evaluating those standards; and 3) results of the five-year experiment that tested the efficacy of six different artificial reef designs in meeting these performance standards. Initial colonization by macroalgae was high on all reef designs. Overall, the abundance and species richness of macroalgae steadily declined over time while the abundance and species richness of sessile invertebrates steadily increased. The abundance of sessile invertebrates was positively correlated with the bottom coverage of reef material. The fish observations suggest that all six reef designs tested provide suitable habitat for kelp forest fishes and most likely would meet the SONGS performance standards for fish.

14 EVALUATION OF KELP (*MACROCYSTIS PYRIFERA* (L.) C. AGARDH) KELP RESTORATION OFF TAJIGUAS, CALIFORNIA USING SCATTEREDGRANITIC BOULDERS IN A SAND HABITAT

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The Tajiguas Kelp Habitat (TKH) was constructed May 6, 1999, in a 0.72 ha area offshore of Tajiguas, California at water depths between 8.5 and 10.4 m (MLLW). It's in relatively pristine waters (they receive minimal pollutants from urban development), sea otters are present occasionally, and casual observations over 20+ years indicate that *Macrocystis* juvenile recruitment events occur consistently. TKH performance satisfied California Coastal Commission mitigation requirements specifying construction of a new kelp habitat that would produce by November 2002, at least 470 adult plants living more than one year. In addition to meeting mitigation requirements, its performance is also meeting long-term criteria for creating a persistent kelp habitat by converting a sand habitat, where kelp persistence was low, into one that provides substrate for kelp recruitment and anchorage and that has minimal destructive sea urchin grazing problems. Design features to help meet long-term criteria, included: (1) Placing granitic rocks into sandy areas where the sand covering the bedrock was too shallow to allow complete rock burial. (2) Spacing rocks so, for the most part, they did not touch each other, thereby minimizing the number of habitats where sea urchins would be protected from predators. (3) Locating TKH adjacent to a natural kelp bed growing on bedrock that could provide TKH both a source of spores for recruitment, if artificial kelp propagation techniques failed, and sea urchin predators (invertebrate and fish) to help prevent destructive sea urchin grazing that occurs in other Tajiguas area kelp beds.

15 "FLOATING" BEHAVIOR OF GRANITIC BOULDERS USED TO CONSTRUCT THE TAJIGUAS KELP HABITAT ON A SAND PLAIN AND COMPARISON OF THE DEVELOPING EPIBIOTIC INVERTEBRATE ASSEMBLAGE WITH NEARBY NATURAL REEF ASSEMBLAGES

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Following removal of underwater pipelines through kelp beds in Santa Barbara County, we were asked to create an artificial kelp habitat offshore of Tajiguas. In response, the rocky 0.7 hectare Tajiguas Kelp Habitat (TKH) was constructed in a thin layer of sand over bedrock offshore from a natural kelp reef. Approximately 1,140 quarry rocks ≥0.6 m in diameter were scattered over the project area to provide ~16 percent of the seafloor. We monitored: "floating" behavior of 30 randomly selected rocks; and sand depth throughout TKH for 18 months. Recently, we conducted a 5-year survey to assess long-term conditions of the rocks and the epibiota.

In areas where sand overburden was less than 0.3 m deep prior to habitat construction, sand washed out and the introduced rocks were resting on exposed bedrock. In areas with deeper sand, the boulders were still basically "floating" on the sand. Thus, the rocks appear to provide long-term substrate suitable for kelp recruitment and survival.

The rich epibiotic assemblage that has developed on the rocks comprises a variety of primarily ephemeral suspension-feeding invertebrates dominated by bryozoans, hydroids, tunicates, and sponges. A comparison with the mature epibiota on nearby natural reefs suggests that the TKH epibiota is at an early stage of succession. Differences in species composition are probably driven by differences in disturbance, relief, and habitat "age".

Dense beds of large tubicolous polychaetes (*Diopatra ornata*) have developed in interstices among the rocks within TKH. These probably contribute more to fish biomass than any other species.

16 COMPARISON OF REEF FISH ASSEMBLAGES AMONG NATURAL ROCK HABITATS AND THE CREATED TAJIGUAS KELP HABITAT IN THE SANTA BARBARA CHANNEL

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Mitigation of natural resource damage may require directed restoration or creation of in-kind habitat. Typically, a mitigation project begins by manipulating abiotic factors (if necessary) at the targeted site and then establishing the foundation or architectural species, such as giant kelp, that defined the damaged habitat, with the expectation that missing species will have the potential to colonize the new habitat by natural or artificial means. To understand how reef fish assemblages responded to a created giant kelp habitat, we describe patterns of species composition and abundance at a manipulated area, the Tajiguas Kelp Habitat (TKH), and six reference sites within the Santa Barbara Channel region. The six reference sites represent a range of potential fish assemblages found within the study region, and were used to formulate simple "standing stock" performance measures to determine if TKH successfully met expectations. Performance measures included minimum levels of species richness and diversity, and whole-assemblage requirements based on degree of similarity to nearby versus distant reference sites. TKH met or exceeded all of these "standing stock" performance measures. Ideally, successful mitigation integrates the new habitat across larger temporal and spatial scales, emulating ecological trajectories (e.g. population dynamics, successional stages) of reference systems. These kinds of trajectories have not been measured at TKH, and require further investigation.

17 POSITIVE INDIRECT EFFECTS OF REEF FISHES ON GIANT KELP PERFORMANCE

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Previous studies have suggested that microcarnivorous reef fishes may regulate or reduce grazing invertebrates, yielding positive indirect effects on giant kelp performance, thus preventing infestations that could have severe impacts or potentially destroy kelp forests. In 2003, I examined the effects of invertebrate herbivores on giant kelp performance in the presence and absence of their predators on plots of giant kelp in three treatments: predator access, predator exclusion, and a cage control. There was a significant increase in invertebrate herbivore density and an effect on kelp performance on plots of giant kelp in which predators were excluded than on plots open to predators. Cage controls indicated that exclusion pens neither enhanced nor inhibited invertebrate herbivore densities or kelp performance. To determine if my results from the previous experiment apply to continuous reefs, I examined the effects of invertebrate herbivores on giant kelp performance in the presence and absence of their predators within a continuous kelp forest. In 2004, predator exclusion cages were deployed within a giant kelp forest and compared with designated open sections of the forest in a stratified random design with treatments at the edge, middle, and back of the kelp forest. There was a significant increase in invertebrate herbivore density and an effect on kelp performance within the continuous reef. In addition, invertebrate herbivores and microcarnivorous fishes were inversely related among nine kelp forests, suggesting that these effects may occur from small to large scales.

18 MARINE RESERVE DESIGN: DETERMINING AN OPTIMAL SIZE AND LOCATION

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"How big should a marine reserve be?" This is the most common question asked of MPA advocates whose replies are usually subjective based on an intuitive optimization of various objectives. A rule of thumb that 20–50% of targeted habitats should be protected within marine reserves has evolved over the last couple of decades based mainly on stock enhancement ideals for a few well-studied stocks. Here, we advocate a less subjective and more case specific approach based on the protection of critical habitat for entire sets of exploited species over an area large enough to protect individuals during their post-larval life stages. We have developed an algorithm to identify an optimal size and specific location for individual marine reserves based on the importance of habitat to all exploited species, the distribution of these habitats, and the post-recruitment mobility of these exploited species. We applied the algorithm to design an optimal marine reserve to protect twenty exploited species within the hard-bottom habitats of La Jolla, CA.

19 BEHAVIORAL THERMOREGUALTION OF THE LEOPARD SHARK (*TRIAKIS SEMIFACIATA*) IN THE NEARSHORE EMBAYMENTS OF SANTA CATALINA ISLAND, CALIFORNIA

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The leopard shark, *Triakis semifasciata,* is one of the most abundant nearshore elasmobranchs ranging from Baja California, Mexico to Oregon, with particular abundance in the bays of California. Mature female leopard sharks have been observed aggregating in Big Fisherman's Cove (BFC) Santa Catalina Island for over 100 years; however, it is unclear why females aggregate in these shallow areas. During July and August of 2003, the numbers of aggregating sharks were counted in different sections of the shallow embayment at BFC ($n = 36$, mean ± S.D. = 21.52 ± 8.17) and water temperature was simultaneously monitored. Temperatures in the embayment ranged from 17.8–25.8C° (mean ± S.D. = 21.8 ± 1.2). Sharks preferred the warmest areas of the embayment (correlation $r = 0.557$, $p<0.01$) and moved to warmer locations over the course of the day. In addition, acoustic tracking, acoustic monitoring and archival transponder technology (Vemco Ltd., V13, V13-R256, VX32TP-Chat tags respectively) are being used to monitor mature female sharks' body temperature, swimming depth, and movements at Catalina Island ($n = 16$). Acoustically monitored sharks show increased affinity to warmer shallow embayments around the island during the day than at night ($p = 0.01$). Preliminary results from archiving Chat tags suggest that shark body temperature is significantly warmer when in shallow water ($r = 0.43$, $p<0.01$), and that shark body temperature is warmer during the day than at night ($p = 0.01$). This form of behavioral thermoregulation may augment metabolic and physiological functions important for gestating females.

20 MOVEMENT PATTERNS AND HABITAT USE OF OCEAN WHITEFISH (BRANCHIOSTEGIDAE) IN A SANTA CATALINA ISLAND MARINE RESERVE

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Knowledge of fish movement patterns over varying temporal and spatial scales is essential for effective management of fish populations. This study integrates acoustic telemetry and a GIS to quantify movement patterns, home range, site fidelity, and habitat use of ocean whitefish (*Caulolatilus princeps*) at the Catalina Marine Life Refuge (CMLR) located at Santa Catalina Island, California. Ten individuals were tagged with acoustic pingers (2 month battery life) and actively tracked to measure fine-scale movements and home ranges over multiple 24hr periods. Home ranges based on 95% kernel utilization distributions range from 90–348,966 m^2, averaging 50,876 ± 110,094 m^2 (± SD). Individuals tracked were active during the day, using soft sediment habitats, but were inactive at night, taking refuge near rocky reefs. An additional seventeen fish were tagged with coded acoustic transmitters (1yr battery life), yielding continuous presence/absence information within and adjacent to the CMLR. To date (~8 months), 88% of the individuals acoustically monitored have shown longer-term fidelity to home ranges within the study site as well as consistent diurnal activity. Ocean whitefish home ranges extend beyond the reserve boundary, making this reserve less effective for protecting adult fish.

21 THE FISH ASSEMBLAGE OF AN ARTIFICIAL AND NATURAL REEF IN THE HORSESHOE KELP

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Horseshoe Kelp is an extensive fish habitat near the Port of Los Angeles composed of several substrates types, including low relief and high relief rocky reefs, *Laminaria* beds, and coarse sand bottoms. As a result of the Deep Draft Improvement Project conducted by the U.S. Army Corps of Engineers and the Harbor Department of the Port of Los Angeles, hard bottom habitat was lost along the northern edge of Horseshoe Kelp (USACE 1997). Due to its proximity to the port, commercial and sport fishers currently and historically have utilized this area extensively. In 2001, a mudstone fishing reef was added to mitigate lost hard bottom habitat in the Horseshoe kelp. The newly created Fishing Reef, a nearby rocky reef, and *Laminaria* reef control habitats were monitored continually between September 2001 and October 2004 using underwater visual census methods. Fish transects were completed on the Fishing reef, a natural reef and the *Laminaria* beds during each sampling period. This interim assessment found that the turbidity, which was noted after reef construction, caused difficulties for sampling, persisted through Fall 2003 and abated in Spring 2004. Fish density was significantly lower on the Fishing Reef than the rocky reef control, but not the *Laminaria* reef control. This is an indication that the Fishing Reef is continuing to mature. Nonetheless, important fishery species including kelp bass (*Paralabrax clathratus),* California sheephead (*Semicossyphus pulcher*), barred sand bass (*Paralabrax nebulifer*), lingcod (*Ophiodon elongatus*), California scorpionfish (*Scorpaena guttata*) and calico, gopher and vermilion rockfishes (*Sebastes* spp.) were found on the newly created Fishing Reef.

22 EFFECTS ON NEARSHORE ROCKY REEFS FOLLOWING THE REGIONAL BEACH SAND PROJECT

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Over the past two decades, San Diego's shoreline has experienced chronic and continuing erosion. In an effort to restore many of the beaches, in 2001, SANDAG implemented the Regional Beach Sand Project which dredged just over two million cubic yards of sand from four offshore borrow sites and replenished 12 beaches along the coast of San Diego County. Concern from resource agencies and

commercial fishermen regarding the potential for the sand placed on the beaches to impact nearby reefs promulgated monitoring of rocky intertidal, shallow subtidal, and kelp forest habitats in the vicinity of select receiver sites. Since implementation, there has been varied response and this presentation will discuss four years of shallow subtidal and beach profile monitoring data regarding coastal processes and its effect on nearshore reefs.

23 EVALUATION OF EELGRASS MITIGATION AND FISHERY ENHANCEMENT STRUCTURES IN SAN DIEGO BAY, CALIFORNIA

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In 1997 to offset habitat loss and increase fishery production an eelgrass mitigation habitat was completed in San Diego Bay, California. This mitigation effort consisted of the transplantation of eelgrass, *Zostera marina,* in the lower portion of the bay. In addition to the establishment of a new eelgrass bed, four artificial reefs made of either quarry rock or concrete were created to further enhance fishery stocks and area's ecosystem. Two design criteria and a direct comparison between quarry rock and concrete reefs were examined in this pilot program. These rocky-reefs and eelgrass habitats were monitored for five years by scuba. The newly created eelgrass habitat quickly performed at the level of the existing eelgrass bed and the overall analysis found that the mitigation eelgrass habitat was not significantly different from the reference eelgrass habitat in terms of fishes. Neither reef material (quarry rock or concrete) nor original reef design influenced fish utilization. In addition, aspects of fishery enhancement were examined using three species of rock bass from the genus *Paralabrax* (Perciformes: Serranidae). All age classes of kelp bass, *Paralabrax clathratus,* were present throughout the study. The density and distribution spotted bay bass, *P. maculatofasciatus,* indicated they utilized these enhancement reefs for foraging. Finally each age class of barred sand bass, *P. nebulifer,* significantly predicted the subsequent age class. This indicates that these modules were successfully in providing habitat for recruitment and subsequent development through adulthood. Using artificial reefs and eelgrass transplantation, enhancement and mitigation goals were achieved in San Diego Bay.

24 LESSONS LEARNED, A HALF-CENTURY OF GIANT KELP RESTORATION IN SOUTHERN CALIFORNIA

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In the late-1950s attention was drawn to the loss of several kelp beds up and down the coast of southern California. Investigators such as Dr. Wheeler J. North began early investigations into the cause of the loss of kelp beds. These early investigations focused on the sometimes subtle effects of mans encroachment on the environment. Searching for answers, Dr. North found the unhealthy kelp beds infested with urchins, but urchins were normal in other kelp beds and did not cause substantial problems. Dr. North and his colleague Dr. Mary Clark, research scientists at CalTech determined that the interaction of sea urchins and sewage was responsible. With the determination that urchins were a large part of the equation in the disappearance of certain kelp beds, methodologies were sought to eliminate excess urchin populations and restore the kelp beds. Unrecognized in the early 1950s and 1960s, the effects of El Ninos and La Ninas also showed the role they play in the viability of our coastal kelp beds.

Two basic techniques were pioneered by Dr. North to restore kelp beds. These include the transplantion of juvenile, subadult, and adult kelp from existing beds using several techniques for attachment and the laboratory growth of sporophytes and their outplanting. Both methodologies have been used successfully but can have vastly different results depending on the ecological interactions in the area being restored.

One of the criticisms of restoration efforts is that it is a non-issue and that natural cycles will take care of the problem, some years are good and some are bad for kelp. We will explore this issue in relation to the probability of its applicability. Another criticism is that most of the growth of the restoration site is from natural revegetation, and that transplant efforts only contributed a minuscule portion of the kelp now present at the site. We will also determine if this criticism is credible.

We will look at several giant kelp restoration projects conducted in the past half-century to glean lessons to use to determine whether, where, and even if, giant kelp restoration projects should be attempted as a viable option today.

25 GIANT KELP RESTORATION AND MONITORING IN SANTA MONICA BAY

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Giant Kelp, *Macrocystis pyrifera,* is a large brown algae that forms canopies, on the oceans surface. These algal beds provide bio-genic structure that attracts a great diversity of organisms. Persistent anthropogenic pressures and changes in oceanographic regimes have reduced the aerial extent of kelp communities within Santa Monica Bay. Historic kelp beds are restored through sea urchin relocation, sporophyll bag deployment, transplanting drifting kelp and outplanting laboratory cultured kelp. Monitoring is performed annually on reference, control, and restoration sites. Quadrat and band transect methods are used to determine the density and diversity of a suite of benthic organisms within these sites. Roving fish counts, adapted from REEF are used to determine the density and diversity of fishes within the same sites. To date 4,500 square meters of rocky reef have been restored into a giant kelp bed off of Malibu. Early data indicates the formation of kelp canopy within 8 months of the initiation of kelp restoration. Increases in the density of fish by 10 to 100 fold have been described. Increases in the diversity of fish species has increased by 18%. This project incorporates volunteers who are trained to assist project biologists with the restoration and monitoring.

26 COMPARISON OF DIGESTIVE ENZYME ACTIVITIES IN TUNAS AND THEIR ECTOTHERMIC RELATIVES

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Tunas are known to elevate the temperature of their aerobic locomotor muscle, and some tuna species can also maintain elevated visceral temperatures. Tunas are effective predators, swim continuously, and have high metabolic rates. Their diet consists primarily of large quantities of protein and lipids. In tunas, the largest visceral organ is the caecal mass, which is thought to increase the surface area for digestion and absorption. This study was a comparison of digestive enzyme activities in tunas and their close ectothermic relatives, to test the hypothesis that enzyme activities are greater in the endothermic tunas. Two tuna species [yellowfin tuna (*Thunnus albacares*), a species that warms its muscle but not its viscera, and albacore tuna (*Thunnus alalunga*), a species that warms both the muscle and viscera] were compared with the ectothermic chub mackerel (*Scomber japonicus*) and eastern Pacific bonito (*Sarda chiliensis*). The specific activities of pepsin in the stomach and lipase in the caecal mass and intestine were measured at 15°C and 25°C and trypsin in the intestine and caecal mass were measured at 20°C and 25°C, with spectrophotometric assays. It was predicted that the caecal mass of endothermic species would exhibit higher digestive enzyme activities than that of non-endothermic species. High enzymatic activities in the caecal mass would support its importance in digestion. If enzymatic activities were significantly higher in the endothermic albacore at its elevated visceral temperature, this would suggest elevated visceral temperatures is likely to speed up processes of absorption and digestion.

27 STRUCTURAL COMPLEXITY OF SEAGRASS INFLUENCES PATTERNS OF RECRUITMENT OF FISHES IN SAN DIEGO BAY

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Processes affecting recruitment are important determinants of population structure and dynamics in marine fishes. Habitat structural complexity may influence recruitment success by providing refuges from predators, enhancing food availability, and influencing settlement by moderating current flow or velocity. The goal of this project was to determine how differential structural complexity of the eelgrass *Zostera marina,* an abundant habitat in San Diego Bay, influenced recruitment of fishes. We cross-factored shoot density with shoot height with standardized habitats in deploying artificial seagrass units (ASUs) at several sites within the bay. Recruits of all fishes were collected after 2-wk periods in each of 5 trials. Approximately 250 recruits from 12 species were collected. Recruitment among the six more abundant species revealed differential responses to habitat structural complexity, with recruitment varying with shoot height, shoot density, and with no difference among treatments. We also conducted an experiment to determine whether predators moderated the abundance of recruits in treatments of predator access and exclusion, using a standardized shoot height and density. There was no significant difference in recruitment to predator access, predator exclusion and cage control treatments. Taken together, the results of these experiments reveal species-specific responses to seagrass habitat structural complexity that appears to be more a result of habitat selection than post-settlement predation.

28 TRANSITIVITY AND SONG PREFERENCES IN THE HOUSE CRICKET, *ACHETA DOMESTICUS*

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Understanding how animals choose between alternative options is a fundamental problem in behavioral ecology. Traditionally, models of decision-making utilized in animal behavior have assumed rationality and value maximization. In other words, individuals have complete ranking of all of their options and have infinite processing time and power to differentiate among them. Few, if any, studies have examined if these assumptions hold in the context of mate choice and none have been done utilizing invertebrates. Male crickets utilize relatively simple signals made up of repeated pulses of sound to attract females. In this study, we tested the hypothesis that female *Acheta domesticus* exhibit transitivity with regard to song choice. That is, given that a female prefers song a to song b and song b to c, they should prefer song a to song c. We tested this hypothesis using a binary choice apparatus and 3 songs that differed in the number of pulses per chirp and chirp rate. We tested the preference of individual females for song 1 versus song 2, song 1 versus song 3 and song 2 versus song 3. Females generally preferred songs with higher chirp rates but female choices did not exhibit transitivity. That is, an individual females preference for one song over another could not be predicted based on previous choices. These data suggest that females are not utilizing a decision-making process grounded in principles of value maximization and rationality as has been previously assumed.

29 ACOUSTIC TRACKING AND MONITORING OF CULTURED JUVENILE WHITE SEABASS RELEASED INTO SOUTHERN CALIFORNIA EMBAYMENTS

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Since 1986 over one million cultured white seabass, *Atractoscion nobilis,* have been tagged and released in southern California as part of the Ocean Resources Enhancement and Hatchery Program. Just over 1,200 of these fish have been recovered through various sampling methods. However, only limited information regarding the short term movement patterns and survival of cultured seabass is known from these results. To increase our understanding of these processes, we surgically implanted acoustic pingers in the peritoneal cavity of 58 cultured white seabass ($\bar{X}$ SL = 27 cm) during the past three years. After surgery, fish were held in captivity for 2–5 weeks to assess their healing prior to release. Acoustically tagged seabass were released as part of a larger group of cultured fish into several embayments within southern California. The fish were tracked actively from a small vessel and passively using an array of moored hydrophones. Emigration rates from embayments ranged from 37 to 57%, with most of these individuals leaving the embayment by the fifth day after release. Mortality rates were inferred from tags recovered from the sea floor. Mortality during the first month following release ranged from 20 to 40%. Strong circumstantial evidence suggested that top predators of cultured white seabass include birds, harbor seals, and octopuses. Of the seabass that were last heard from in embayments, 26 % were ultimately unaccounted for.

30 LACTATE PROCESSING IN ENDOTHERMIC AND ECTOTHERMIC SHARKS

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When sharks burst rapidly for prey capture or predator avoidance they undergo anaerobic metabolism in their fast-glycolytic white muscle (WM), producing lactate. The endothermic mako shark has a higher capacity to produce lactate than the ectothermic leopard shark; therefore it should process lactate at a higher rate. There is evidence that most of the lactate is reconverted to glycogen within teleost fish WM, but lactate processing has not been examined in sharks. The shortfin mako shark (*Isurus oxyrinchus)* was compared with the leopard shark (*Triakis semifasciata*) to test the following hypotheses: (1) the mako shark will have higher activities of enzymes required for glycogen synthesis (pyruvate carboxylase-PC, phosphoenolpyruvate carboxykinase-PEPCK, malic enzyme-ME, and fructose-1,6-bisphosphatase-FBPase) in WM than the leopard shark and (2) within each species, activities of these enzymes will be higher in WM than in liver, heart, or red muscle. Lactate dehydrogenase activity (an index of lactate production) in WM was higher in the mako than in the leopard shark, as expected. Neither PC nor PEPCK activity was detected in WM, and there were no significant interspecific differences in FBPase or ME activity. PEPCK activity in liver was significantly higher in the mako. The only significant difference among tissues was that mako PEPCK was higher in the liver than in the heart. Therefore, neither hypothesis was supported. The results indicate that glycogen synthesis from lactate within WM in these sharks cannot occur unless an alternative route for pyruvate to phosphoenolpyruvate exists.

31 LATE PREHISTORIC CERAMIC PRODUCTION IN THE UPPER MOJAVE RIVER REGION, SAN BERNADINO COUNTY, CALIFORNIA

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Petrographic analysis of twenty-five ceramic sherds from the Deep Creek and E.S. Young sites, located in the upper Mojave Region of southern California, was undertaken in order to test the assumption that brown wares were locally produced and not intrusive in archaeological assemblages of the late prehistoric period in Southern California. Mineralogical analysis of ceramic thin sections, and samples of clay, sand, and gravel from the catchment areas surrounding the sites, allowed for the distinction of local versus non-local ceramic products. Results indicate that brown ware ceramics recovered from both sites were likely produced in the immediate vicinity of the sites and that these brown wares have unique characteristics which distinguish them from other brown wares found in southern California. No definite location of manufacture of buff wares could be determined, indicating that they may have been imported from another region.

32 ARCHAEOFAUNAL RESEARCH AT LATE HOLOCENE PREHISTORIC SITES ON SAN NICOLAS ISLAND: RECENT EXCAVATIONS AND EXPERIMENTAL STUDIES

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Results of recent archaeofaunal research from two late Holocene prehistoric sites in the Central Plateau of San Nicolas Island are presented. During fall 2004, test excavations were conducted at CA-SNI-44 by a field class from the Department of Anthropology at CSUF. Although earlier archaeologists thought the site had been essentially destroyed by construction activities on the island, our recent excavations indicate that intact prehistoric cultural deposits are present, including well-preserved fish and marine mammal remains. Archaeofaunal investigations at another nearby site on the Central Plateau, that of CA-SNI-102, are also discussed. As a means of explaining the burning patterns observed on fish remains at CA-SNI-102 and other prehistoric sites on San Nicolas Island, an experimental study of fish processing and cooking was conducted, the results of which are presented. Future directions of the archaeofaunal research at these two sites and their implications for understanding overexploitation and resource depression in the late Holocene are discussed.

33 ARCHAEOLOGY AT THE HARVARD HILL SITE, SAN BERNARDINO COUNTY, CALIFORNIA

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McKenna et al., under the direction of the San Manuel Band of Mission Indians, Highland, has been working on the Harvard Hill archaeological site in San Bernardino County. The site is a large, prehistoric occupation area yielding dates of 600 ± 30 years B.P. (ca. A.D. 1400) and representing an extensive scatter of materials indicative of a trade center with multiple occupations. Materials recovered from the site include shell, alphaltum and lithic materials associated with coastal California as well as projectile points, ceramics, and other items indicative of eastern California (the Mojave Desert and Great Basin), indicating an extensive array of items representing virtually all areas of Southern California. This site, in conjunction with other well documented sites in the area of Barstow and the Mojave River, is evidence that an elaborate trade system existed in the area of the Mojave Desert while other areas of the greater Southwest were experiencing a significant decline in population and exchange.

34 TWO RITUAL CACHES FROM CA-ORA-950: A WINDOW ONTO THE SYMBOLOGY OF COGGED STONES

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Within single cogged stone caches, two cogged stones with identical counts of cogs constitute a "matched pair." Three matched pairs were identified for two cogged stone caches at a Lake Forest, Orange County site. One of these caches also contained an elongate artifact that is probably a fertility/fecundity symbol. The CA-ORA-950 evidence, coupled with that of three caches from two other sites, supports the hypothesis that regional Early Holocene iconography embraced dualistic symbology.

35 PREHISTORIC ADAPTATIONS TO COASTAL WETLANDS: AN 8,000 YEAR VIEW FROM SANTA MONICA BAY, WEST LOS ANGELES

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For over 8,000 years, aboriginal peoples have lived and adapted to the changing environments of the Ballona Lagoon, a drowned river valley located on Santa Monica Bay, West Los Angeles. During this time, the coastal environment, including the Ballona Lagoon itself, has altered significantly with resulting changes in human behavior. This, in addition to a melding of cultural traditions from both the coast and desert, led to a complex social dynamic that flourished in the Los Angeles Basin. Research by Statistical Research, Inc. (SRI) and others at nearly 25 archaeological sites in the Ballona region offers a unique view into human adaptations to coastal wetlands.

36 OPTIMAL RESOURCE PRODUCTION: A MODEL OF CHUMASH IMPACT ON THE ENVIRONMENT IN THE SANTA BARBARA CHANNEL AREA

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The management of natural environments to reach an optimal level of resource production represents a concept that induces archaeologists to generate new interpretations of past cultural depositions. Among these interpretations, prehistoric societies positive/negative impact on the environment along the California Coast present the Chumash as a possible model group for the study of such impacts. The prehistoric long habitation span and high population density of the Chumash along the Santa Barbara Channel coastal area provide evidence in support of a well developed natural resource management program. Using archaeological and ecological applications, this paper presents a possible *optimal resource production* model for an understanding of Chumash relationship with their environment. Within this model, prehistoric Chumash populations appear as colonizers of various micro-ecosystems within their geographic area. These areas, previously disturbed only by natural successions, offered the Chumash a large variety of resources. The *optimal resource production model,* in combination with middle Holocene archaeological evidence, provides a way for studying the maximization of natural resources and their negative/positive impacts on the environment. Attention is given to the climatic changes during the middle Holocene period along the Santa Barbara Channel area and the switch to a more intensified use of land resources. Climatic fluctuations in combination with the use of fire to maximize land resources appear to explain the Chumash impact on the environment within the *optimal resource production model.*

37 "JUNE GLOOM" AND "TULE FOG": CONSIDERATIONS OF THE IMPORTANCE OF CLOUD MOISTURE FOR PREHISPANIC SETTLEMENT AND SUBSISTENCE STRATEGIES IN SOUTHERN CALIFORNIA

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In 1965, Edward P. Lanning published the volume **Peru Before the Incas.** This landmark work clearly established the importance of "lomas agriculture" (the subsistence practices based on vegetative islands formed with coastal fog moisture) as one of the principal features of early human sedentism and the basis for further cultural development on the Pacific coast of Peru. Although similar fog moisture conditions exist on the Pacific coast and in some inland valleys (San Joaquin and Sacramento) of California, their potential importance for affecting prehispanic settlement and subsistence has been generally overlooked. This paper summarizes available climatic and archaeological data from two distinct locations (1) the southern coastal Orange County region, and the (2) more inland San Joaquin and Sacramento Valley regions. On the basis of these preliminary analyses, this paper concludes that the data indicate that, as in Peru, fog moisture played a significant, if geographically limited, role in prehispanic California. Archaeologists conducting research in California are encouraged to integrate theoretical and methodological considerations of fog moisture adaptation with future research and interpretation.

38 PALEOCLIMATE AND VEGETATION RECORD IN THE LATE PLEISTOCENE PALOS VERDES FORMATION ("OLDER ALLUVIUM") IN THE SAN FERNANDO VALLEY, SOUTHERN CALIFORNIA

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Microfossil samples collected from a 50-foot section of Palos Verdes Formation (''Older Alluvium'') exposed in excavations near ''beautiful downtown Burbank'' have produced an unusual Late Pleistocene pollen and spore flora. Surprisingly, the dominant palynomorphs in almost all samples are fern and club moss spores (>40%), followed by pollen of Compositae (~10%), and alders (~5%); all three of these plant groups are common pioneer species colonizing ecologically disturbed areas. This unusual pollen and spore assemblage appears to record ecological disturbance due to glacio-eustatic sea level fluctuations. These fluctuations may have resulted in a rather wide coastal plain with frequent perturbations to the local vegetation. The frequency of disturbances favored opportunistic species that could invade open habitats and reproduce rapidly and prevented the development of ecological climax forests. Samples from a depth of 46–48 feet and from a paleosol at approximately 4–6 feet appear to represent more mature or climax plant communities with greater diversity and more tree species. The palynoflora from these samples include plant species whose modern equivalents live along the coastal summer fog belt in northern California. These modern occurrences suggest that the Late Pleistocene maritime climate that characterized the area was cool, wet, and less seasonal or more equable, in sharp contrast to the strongly seasonal Mediterranean climate with hot, dry summers and warm, wet winters that exists in the region today. Thus, the portion of the Palos Verdes Formation stratigraphic sequence sampled was probably deposited during a glacial-pluvial (cool rainy) stage of the Late Pleistocene.

39 REVISED CORRELATION AND AGE ASSIGNMENTS OF FOSSIL LAND MAMMAL ASSEMBLAGES OF LATE HEMINGFORDIAN TO EARLIEST HEMPHILLIAN (EARLY MIDDLE TO EARLY LATE MIOCENE) AGE IN CALIFORNIA, NEBRASKA, AND TEXAS, BASED ON OCCURRENCES OF TICHOLEPTINE OREODONTS (MAMMALIA, ARTIODACTYLA, OREODONTIDAE, TICHOLEPTINAE) AND OTHER LAND MAMMAL TAXA

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The Green Hills Fauna (F) (low. Resistant Breccia Member [RBM], Barstow Fm. [BF], CA) contains *Brachycrus laticeps,* correlates with the Sheep Creek (type Hemingfordian [He]) and Low. Snake Creek Fs of NE, and is late He, not early Barstovian (Ba). The Second Division F (up. RBM) is latest He. The overlying Low. (type Ba) Barstow F (low. Fossiliferous Tuff Member [FTM], BF) contains endemic *Mediochoerus mohavensis mohavensis* (not *Merychyus medius ?schrammi*) and is early (not late) Ba, while the late Ba, Up. Barstow F (up. FTM) includes the first appearance of the cricetine *Copemys russelli.* The latter three Fs lack definite correlatives in NE. The *Ustatochoerus profectus* (= *M. medius*)/*C. russelli* Assemblage Zone (AZ) (Dove Spring Fm. [DSF] Member 2, CA) contains *M. m. compressidens,* correlates with the Minnechaduza F of NE, and is early Clarendonian (Cl), not late Ba. The latter F overlies the Devil's Gulch F, which contains large *M. m. medius* and correlates with the earliest, type Cl, Low. Clarendon F of TX. The low. *Cupidinimus avawatzensis*/*Paracosoryx furlongi* AZ (DSF Member 3) contains *M. major santacruzensis,* is early late (not early) Cl (pre-Cerrotejonian), and correlates with the Xmas-Kat Local (L)F of NE. The low. (but not basal) *Paronych-*

omys/Borophagus littoralis AZ (DSF Member 6; contains Hemphillian [Hh] index taxon/antilocaprid *Ilingoceros*) and the Kendall-Mallory LF (Orinda Fm., CA) contain *M. ma. ?profectus* and the cricetine *Paronychomys,* correlate with the Snake Creek F of NE (contains *M. ma. ?profectus* and megalonychid sloth), and are earliest Hh (post-Montediablan), not late Cl.

40 CACHE OF FOSSIL REMAINS FOUND IN SAN QUINTIN, BAJA CALIFORNIA LOCATED WITHIN A BEACH CLIFF CAVE

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An ongoing multi-disciplinary cave excavation, located 11 meters above sea level in San Quintin, Baja California, has revealed a variety of faunal remains. The cache includes predominantly carnivorous mammalian species: puma, *Felis concolor,* coyote, *Canis latrans,* grey fox, *Urocyon cinereoargenteus,* sea otter, *Enhydra lutris* and ringtail, *Bassariscus astatus.* Other mammals found in the cave consist of kangaroo rat, *Dipodomys agilis,* and two rabbit taxa: *Sylvilagus sp.*and *Lepus californicus.* In addition, the remains of three species of bird and a whale are represented though yet to be definitively identified. The explanation for the presence of such a diverse collection of faunal remains in one isolated beach cliff cave can be hypothesized by applying a plausible anthropological construct to the data. The indigenous group, Kiliwa, historically established themselves in the San Quintin region approximately 1000 AD. As a seasonal nomadic group, they moved across Baja California's high sierras, San Pedro Martir, and possibly the Gulf of California. Certain animals that were found in the cave were seized and possibly killed in the high sierras, and were then transported to the cave by the Kiliwa people, for ceremonial rituals conducted by Kiliwa shamans.

41 ADSORPTION OF SYNTHETIC PYRETHROIDS ON SEDIMENT

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Adsorption on sediment regulates the fate and bioavailability of contaminants in the aquatic environment. A common way to measure adsorption capacity of organic compounds in soil or sediment is to use the batch equilibration—solvent extraction method in which the solid and aqueous phases are separated by centrifugation and the aqueous phase concentration C_w is determined after exhaustive solvent extraction. However, this method may give artificially depressed K_d for strongly adsorbing compounds such as pyrethroids, as small colloidal particles and dissolved organic matter are not eliminated from the aqueous phase and contribute to the measured C_w. Solid phase microextraction (SPME) selectively detects the freely dissolved concentration and thus may be used to improve K_d measurement. We determined K_d values for eight pyrethroid insecticides using both solvent extraction and SPME to measure C_w. K_d obtained with SPME was 2–100 times greater than that with the solvent extraction method, and the difference was more significant for sediments with higher organic matter content. K_d measured with SPME is expected to be useful for predicting the bioavailability or toxicity of sediment-borne pyrethroids, as it correlates with the free or bioavailable concentration.

42 SURVEY FOR SYNTHETIC PYRETHROIDS WITHIN THE SAN DIEGO/NEWPORT BAY WATERSHED

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The Upper Newport Bay is an ecological reserve located within Orange County, CA. It is a marine estuary that provides habitat for nearly 200 species of birds, and several species of fish, mammals and native plants. The primary freshwater inlet for the estuary is the San Diego Watershed, which is the primary drainage area for the cities of Santa Ana, Tustin, Lake Forest and Irvine. With the increasing encroachment of urban sprawl, there has been a dramatic shift in land use within the San Diego Watershed from agricultural to urban landscapes. There is a concern that this shift in land use will result in an increase of non-source pollution from individual homesteads that use pesticides to aid in ant and weed control. The use of pyrethroids has increased steadily in both agricultural and urban settings as a replacement for organophosphate insecticides. In addition, nursery use has also increased drastically since 1995 as mandated for red and imported fire ant quarantine. Pyrethroids commonly

have high aquatic toxicity, and contamination of surface streams by pyrethroids is of concern. The objective of this study was to determine the presence and spatial variability of pyrethroids within the watershed. Eighteen sediment grab samples were taken from locations within the watershed. Five of the samples were collected at the outlets of existing nurseries. The rest were collected within drainage channels and Upper Newport Bay. Samples were analyzed for pyrethroids using GC-ECD. The frequency, location, and levels of pesticide detections will be presented at the meeting.

43 THE EFFECT OF FEMALE CHEMICAL CUES ON THE AGGRESSIVE BEHAVIOR OF MALE CRICKETS, *ACHETA DOMESTICUS*

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Male crickets, *Acheta domesticus,* show aggressive behavior to gain opportunities for reproduction over other males. Female crickets show a preference towards more aggressive and larger males. Female chemical cues along with residency status should influence male aggression. We hypothesized that aggression would increase with higher levels of female cues and that residents should be more likely to exhibit aggression in the presence of female cues than in their absence. We observed male fights in 14 cm × 26 cm containers with a sand substrate. These containers had previously housed no females, one virgin female, or two virgin females for 48 h prior to the trials. We found no effect of female chemical cues on the amount of aggression. Chemical cues also had no influence on the aggressive behavior of the resident or intruder. We also found that resident status, weight differences, or age differences between residents and intruders did not predict the outcome of the interactions. We did find that the intensity of aggression could be predicted based on the age of resident and intruder males. Older residents and younger intruders were more likely to be aggressive. Our results suggest that residency status and perceived territory quality do not influence aggressive interactions in male house crickets. In addition, these data suggest that age and residency status may be important factors influencing a male's decision to fight. We hypothesize that this pattern is a product of younger intruders having nothing to lose and the cost of territory loss for older residents.

44 THE EFFECTS OF ARTICHOKE THISTLE (*CYNARA CARDUNCULUS*) DENSITY AND COASTAL SAGE SCRUB INFLUENCE ON PREDATION OF ARTIFICIAL NESTS

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Artichoke thistle, *Cynara cardunculus,* is an invasive plant in California grasslands listed on the noxious weed index of the California Department of Food and Agriculture. It may affect native primary producers and consumers, but its invasion impact has not been fully studied. Thistle invasion changes the habitat structure, thus changing the niche composition. Birds may utilize the flower stalk of this exotic plant as a nesting resource. Thistle may impact nest success by providing camouflage from avian predators for birds nesting in grasslands. A comparison of artificial nest survival was made between thistle invaded grassland and grassland with almost no thistle. We hypothesized that higher nest success would occur with nests in thistle invaded grasslands than in grasslands without thistle, and that artificial nest success would be higher with increasing distance away from the surrounding coastal sage scrub habitat. Twenty nests were placed in each type of grassland at 45 m intervals from coastal sage scrub into the transition of grassland. Each nest was baited with one quail egg and two clay eggs. Predation on the nests was checked at 40 and 110 hours. A nest was noted successful if no eggs were disturbed. More nests were successful in grassland invaded with the thistle (60% success) then in grassland without thistle (40% success). Also, nest success rate increased with distance from coastal sage scrub. Comparing artificial nest survival in artichoke thistle invaded grasslands provides a greater understanding of the impacts of artichoke thistle on the habitat it invades.

45 SEWAGE IS AN UNLIKELY SOURCE OF FECAL INDICATOR BACTERIA IN THE LOWER SANTA ANA RIVER WATERSHED

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The Santa Ana River, CA and adjacent wetlands have been identified as potential sources of fecal indicator bacteria (FIB) to the surf zone at Huntington Beach CA. Fecal steroid chemical markers including coprostanol, epicoprostanol, cholesterol, cholestanol, α-cholestanone, β-cholestanone, β-sitosterol, stigmasterol, stigmastanol, campesterol, and caffeine were extracted by solid phase extraction (SPE) and supercritical fluid extraction (SFE). The results of these analysis and multivariate statistic were used to examine whether sewage was a significant source of FIB within the Santa Ana River watershed. A difference was found in steroid ratios between river samples, raw and treated sewage from a local treatment plant, or nearby effluent plume. The characteristics of the steroid ratios coupled with the strong correlation between coprostanol and turbidity suggested a diagenetic rather than a biogenic source for the coprostanol in the samples. Additional multivariate statistical analysis showed that the concentrations of FIB were better correlated with bird fecal steroids than with typical sewage steroids.

46 DESCRIPTION OF FIELD-COLLECTED LARVAE OF TWO NATIVE FRESHWATER SOUTHERN CALIFORNIA FISHES, *CATOSTOMUS SANTAANAE* AND *GILA ORCUTTI*

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Larval series of the Santa Ana sucker (*Catostomus santaanae,* Federally Threatened) and arroyo chub (*Gila orcutti,* California Species of Special Concern) are described from specimens collected from the Los Angeles and Santa Ana river drainages. *Catostomus santaanae* larvae are elongate. They have 41–46 myomeres and a distinctive paired-triangle patch of melanophores over the midbrain. Melanophores are present on the snout, dorsal body, lateral line, dorsal gut, post-anal ventral body and caudal fin. Pre-anal length equals 74–79% SL, typical of catostomids. *Gila orcutti* larvae are relatively deep-bodied. They have 36–39 myomeres and a distinctive heart-shaped patch of melanophores over the midbrain with a line of melanophores trailing posteriorly. Heavy pigment is present on the snout, lower jaw, dorsal body, lateral line, gill arches, dorsal gut, post-anal ventral body and caudal fin; they have a shorter pre-anal length of 65–72% SL, typical of cyprinids. These two species often occur together, and less commonly with the local native form of *Rhinichthys osculus* (another cyprinid that is a California Species of Special Concern). Characters distinguishing the three from each other and from other local freshwater fish larvae are discussed along with habitat preferences.

47 AXIAL SPLITTING OF SHRUBS IN WET AND DRY ENVIRONMENTS

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Arid regions around the globe are dominated by shrubs of a unique growth form. They possess segmented woody roots and stems that split apart with maturity, often resulting in complete fragmentation. These species are often dominant in their native habitats and include *Larrea tridentata* and *Ambrosia dumosa* in North America, *Zygophyllum dumosum* and *Artemisia herba-alba* agg. in Israel, as well as numerous *Artemisia* species in the northern hemisphere. Many other species posses strongly fluted or segmented axes, but do not physically split apart. Morphological stem segmentation causes axial segmentation of the hydraulic system. Previous research has shown that woody plants from dry environments show a high degree of hydraulic segmentation of the wood, even if they show no signs of morphological stem segmentation. We postulate that axial hydraulic segmentation introduces redundancy into the hydraulic system, increasing survival of the whole genetic individual, but at the cost of losing parts of the plants to drought-induced mortality. We hypothesized that the degree of hydraulic redundancy in shrubs will decrease along aridity gradients from arid to mesic conditions. To test this hypothesis, we documented the prevalence of morphological axis segmentation in shrubs from a variety of genera along North and South American aridity gradients located between 30° and 35° latitude. Along the same gradients we also measured axial hydraulic segmentation at the anatomical level by mapping pathways of water transport in the xylem using injected dye tracers. The results support our hypothesis that hydraulic redundancy in shrubs decreases from arid to mesic environments.

48 EVALUATION OF METHODS FOR DETERMINING CHRONIC TOXICITY IN MARINE SEDIMENTS

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Sediment quality objectives are being developed in the State of California that are expected to include measurements of acute and chronic sediment toxicity. Acute sediment toxicity methods are commonly used, however chronic testing methods have been used on a much more limited basis in California. This study was designed to compare between several available chronic sediment toxicity protocols and guide the selection of methods for use in California. Sediment samples were collected from bays and estuaries in the Southern California Bight and from San Francisco Bay. Split samples from 15 stations were distributed to four laboratories for testing using six methods: a sediment-water interface method with sea urchin (*Strongylocentrotus purpuratus*) or mussel (*Mytilus galloprovincialis*) embryos; a benthic copepod (*Amphiascus tenuiremus*) life cycle test; a polychaete (*Neanthes arenaceodentata*) survival and growth test; an amphipod (*Leptocheirus plumulosus*) survival, growth and reproduction test, a larval clam (*Mercenaria mercenaria*) survival and growth test; and an oyster (*Crassostrea virginica*) lysosomal destabilization assay. In addition, each station was an also tested using acute methods with two species of amphipod (*Eohaustorius estuarius* and *Leptocheirus plumulosus*). Sediment metals, organics, and grain size were analyzed for each station. There was a wide range of results for the samples with between 8 and 80% of the stations being found to be toxic by any given protocol. Each station was found to be toxic by at least one method and no station was found to be toxic by more than five of the six chronic methods. The *Eohaustorius* acute, copepod reproduction, and polychaete growth endpoints had the strongest correlations with sediment chemistry, but also correlated strongly with sediment physical parameters.

49 LACK OF GENDER-BIASED MICROSITE PATTERNS IN *SALIX LASIOLEPIS*

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Previous studies on dioecious plants have demonstrated differences between male and females in terms of the microsites they inhabit. Reported trends in microsite inhabitation for dioecious plants have been that females inhabit moister habitats than males, seemingly to offset reproduction costs. In this study we looked at the distribution of sexes of *Salix lasiolepis* in a .15 mile reach of the Tujunga River in the San Gabriel Mountains (California) in relation to the thalweg of the streambed. We also focused on the relationship of wood density versus sex in *S. lasiolepis* and as a function of current, as well as xylem to lumen ratio versus sex. Based on previous research, we expect to find that female *S. lasiolepis* inhabiting microsites closest to the thalweg and females would exhibit lower wood densities and therefore greater xylem to lumen ratios than males. However, preliminary results indicate that there are no differences in the distribution of males and females in regards to elevation from the thalweg, wood density of males and females and in xylem to lumen ratios in *Salix lasiolepis*. This could be due to two potential reasons. One is because low summer discharge in the Tujunga River places individuals under water stress, regardless of where they occur in the stream channel, and therefore, rely more on ground water than on surface water. The second explanation is that because freezing places an upper limit on xylem conduit diameter for individuals in the channel, increases in vessel diameter that would lead to lower wood density does not occur.

50a MORPHOLOGY AND MOLECULAR PHYLOGENY OF *EGREGIA MENZIESII*

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The morphology of the feather boa kelp, *Egregia menziesii,* varies considerably throughout its range from Canada to Baja California, México. These traits may be genetically fixed or be indicative of a high degree of plasticity. We characterized the distribution of *Egregia* morphotypes at two sites in Oregon and seven in California. Results show variation in the laterals and rachis corresponding with latitude, and all populations showed a transition of lateral type with increasing length as has been previously reported. Sequence differences between Oregon and southern California populations are present in the internal transcribed spacer region between the 26s and 5.8s rDNA genes. This genetic investigation provides baseline data for studying plasticity in temperature tolerance, in terms of heat shock protein (Hsp) production, within and among species over large geographic ranges. Hsps are also produced in response to stressors such as hypoxia, metal ion concentration, and organic compounds. This project will lay the groundwork for using Hsps to study tolerances to climate change and anthropogenic stressors in seaweeds. Additionally, physiological comparisons in response to thermal stress between native species and competitive invaders may help determine if thermal microhabitats facilitate invasions. Since high temperature stress has led to the decline of native kelps in southern California, knowledge of the temperature tolerances and physiological responses of native and invasive kelp species can contribute to efforts for conservation and restoration projects.

50b BIOAVAILABILITY OF PERMETHRIN IN SEDIMENTS AND ESTIMATED WITH SOLID PHASE MICROEXTRACTION (SPME)

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The use of synthetic pyrethroid insecticides (SPs) is increasing in agriculture and urban environments. A recent survey showed that SPs were commonly found in aquatic sediments in the Central Valley of California. Therefore, it is imperative to understand the ecotoxicological implications of SPs in the sediment environment. However, because pyrethroids have a high affinity for sediment and dissolved organic matter, their bioavailable concentrations in sediment systems are expected to be significantly lower than the total sediment concentration. Therefore, their sediment toxicity cannot be evaluated based on the whole sediment concentration. In this study, the bioavailability of permethrin to *Chironomus tentans* larvae in water-sediment systems was investigated. During the bioassays, polydimethylsiloxane (PDMS) fibers were used as a "biomimetic" tool to simultaneously measure the freely dissolved concentration of SPs in water-sediment systems. The concurrent analyses facilitated understanding of the relationship between pesticide phase distribution and the biota sediment accumulation factors (BSAF) with different sources of sediment. Generally, larvae accumulated more pesticide in sandy sediment than silt or clay sediments. The amount of chemicals accumulated on the PDMS fiber was well correlated with body residues. This suggests that chemical partitioning into PDMS "mimics" the bio-uptake process and PDMS fiber may serve as a good surrogate for sediment biota.

51 PRELIMINARY ANALYSIS OF A CAVE FAUNA FROM SAN QUINTIN, BAJA MEXICO

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Preliminary identification of fauna from an ongoing multi-disciplinary cave excavation has revealed puma, *Felis concolor,* coyote, *Canis latrans,* grey fox, *Urocyon cinereoargenteus,* sea otter, *Enhydra lutris,* ringtail, *Bassariscus astutus,* the epiphysis of a large whale vertebra and multiple elements of a large aves. Most of these taxa occur in the San Quintin Valley area today though perhaps not in the immediate vicinity of the coast. Exceptions are the sea otter which was extirpated in 1922 (last historical record) and possibly the large bird bones and whale epiphysis which have yet to be definitively identified. The cave is located in a basalt cliff 11 meters above sea level in the vicinity of Bahia de San Quintin approximately 485 kilometers south of San Diego, Ca. on the Pacific coast. It was formed by a lava tube and has the general dimensions of 1.8 meters high, 2.0 meters wide and tapers to a length of 7 meters. The floor sediment consists of quartz- and feldspar-rich aeolian deposited sand. Similar sand covers much of the cliff-top in the form of dunes 10–20 meters in depth. Previous activity by locals had disturbed the sediments, likely revealing bones in the past. The initial assumption was that all sediments had been repeatedly disturbed. However, test excavation begun in November 2004 revealed abundant skeletal material approximately 15–30 centimeters below the present sediment surface.

52 BOLUS REBOUND KINEMATICS DURING ENGULFMENT FEEDING IN THE RORQUAL WHALES

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Rorqual whales (Family: Balaenopteridae) employ unique filter-feeding structures and techniques to controllably engulf massive amounts of prey-laden seawater while feeding. Engulfed water containing a concentration of prey items forms a bolus that enters the whales' distensible ventral pouch through the buccal cavity. The two-dimensional kinematics of this bolus was analyzed using digital video from three species of surface-feeding rorqual whales in the Gulf of St. Lawrence, Canada. Individual still frames were extracted from video sequences and landmarks were placed on consecutive frames to calculate movement, relative to the animal, of the bolus over 1/30 second frame intervals. The bolus initially translated posteriorly inside the ventral pouch then rebounded off the posterior end of the pouch before traveling back toward the buccal cavity. Velocities and directional changes were quantified, and the momentum of the bolus is thought to help initiate the ram filtration process through the baleen plates. Results showed that *Balaenoptera acutorostrata* has the fastest bolus rebound velocity, followed by *B. musculus* and *B. physalus,* respectively. Further work will be performed to help understand the implications of these findings, including how they contribute to scaling relationships between the sizes of the different species and the volumes of the boluses.

53 THE GREATEST GRUNION HUNT IN 50 YEARS: CALIFORNIA GRUNION SIGHTINGS ACROSS THE SEASON AND ALONG THE COAST IN 2004

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California grunion are marine silversides that appear on sandy beaches in the middle of the night for spawning runs. Their populations are difficult to assess because they rarely come up in trawls, they do not take a hook, and they are almost never seen except during their spectacular midnight runs. Recently we developed a method for training citizen scientists to assess grunion runs in widely dispersed areas and to report them instantly to a central database via an internet-based interface. A series of workshops were held in spring of 2004 to train over 350 volunteer Grunion Greeters from four coastal counties. Runs were monitored on 30 specific beaches from San Diego to Monterey Bay over the course of the closed season (April and May), and early June, for a total of 10 nights. Runs were assessed according to the Walker Scale for strength and duration. Runs were highly variable in space and time. We show data for grunion populations across the spawning season and along the coast to examine possible patterns. Although these data are only one year's effort, the number of dates and beaches represented make this the most ambitious assessment of the California grunion spawning population ever attempted.

54 INTERACTIONS OF NEARSHORE FISH ASSEMBLAGES AND NET-PEN MARICULTURE EFFORTS ON SANTA CATALINA ISLAND, CALIFORNIA

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The Department of Fish and Game has developed the Ocean Resource Enhancement Hatchery Program (OREHP) where mariculture of white seabass, *Atractoscion nobilis,* is occurring along the southern California coast. The effects of white seabass shallow water net-pens used in California mariculture are not described in detail. Preliminary analysis has shown that the presence of the artificial canopy created by a floating net-pen used for mariculture in Catalina Harbor, which is next to a kelp bed (*Macrocystis pyrifera*), attracts fishes to it and creates a similar three dimensional community. These net-pens appear to increase localized production due to feed floating into the ambient environment. We have conducted replicate band transects documenting fish size (total length) and abundance. Variation in water column productivity of fishes has been analyzed by comparing fish densities and size-classes that can be used to estimate biomass of the fish assemblage below the net-pen to those metrics occurring at reference sites. This comparison represents a novel case study for the artificial reef attraction-production controversy, as well as describing ecological change in nearby systems caused by mariculture production of fin fish in southern California.

55 A COMPARISON OF PREVALENCE AND MEAN INTENSITY OF THE ECTOPARASITE *ELTHUSA CALIFORNICA* IN SHINER SURFPERCH (*CYMATOGASTER AGGREGATA*) OF TOMALES AND BODEGA BAYS

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The cymothoid ectoparasite *Elthusa californica* is known to parasitize the opercular cavities of the Shiner Surfperch (*Cymatogaster aggregata*). This study examines the numbers and distributions of *E. californica* found on 92 *C. aggregata* from Nick's Cove, Tomales Bay, CA for geographic and temporal comparisons with previous studies. Specimens were collected via a 6 meter impounding seine, packaged individually and then immediately examined for the presence of *E. californica.* No significant differences were found between the populations of *Elthusa calfornica* in Tomales and Bodega Bay. Isopod and host size were significantly correlated. We suggest that the populations found in both bays could be part of the same overall population.

56 ANALYSIS OF HISTORICAL CHLORDANE LEVELS IN SAN DIEGO AND MISSION BAY IN COMPARISON TO THE THRESHOLD LEVEL OF TOXICITY TO THE AMPHIPOD, *EOHAUSTORIUS ESTUARIUS*

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Chlordane was produced as an organochlorine pesticide from 1945 until 1997 when it was removed from the market. Its primary use was as a general insecticide on home lawns and gardens; it was also commonly used as a termiticide. Chlordane has been frequently found in sediments at levels well above published effects-range guidelines near storm drain and creek inputs in both Mission and San Diego Bay. A Toxicity Identification Evaluation (TIE) is underway to evaluate whether chlordane levels near the Tecolote Creek entrance in Mission Bay are at levels that may explain observed toxicity to the marine amphipod *Eohaustorius estuarius.* Chlordane reference toxicant testing will be performed to determine a threshold level for this amphipod species. The data will then be compared to historical chlordane data accumulated over several years from both Mission and San Diego Bay.

57 SEASONAL BACTERIAL CONCENTRATIONS IN THE LONG BEACH/LOS ANGELES HARBOR COMPLEX; YEAR TWO OF A FIVE YEAR STUDY

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Pathogenic organisms coming from non-point sources into coastal recreational waters have been a long-standing public health concern. Freshwater outlets, such as storm drains, are a particularly high source of contamination, especially in the wet season. Bacterial species such as coliforms and enterocci are used to indicate the likelihood of pathogenic organisms in surface waters. Because elevated levels of these bacteria have been linked as a causal agent of stomach flu and other infections, California Assembly Bill (AB411) established maximum allowable concentrations of these bacteria in recreational waters in 1999. The amount of total coliforms, fecal coliforms (as estimated by *E. coli*), and enterococcus were tested mainly in the Long Beach/Los Angeles Harbor complex seasonally and after the first flush (>0.5 inches rainfall). The results show: 1) instead of "seasonal" variation there is a more prominent wet vs. dry pattern, 2) health limits were exceeded after significant rainfall events, and 3) most concentrations abated by the time outlet plumes dissipated throughout the Harbor. Bacterial concentrations correlated negatively with salinity and positively with turbidity, supporting previous studies. The data represent two years of sampling within a 5-year monitoring project, providing data on the dynamics of bacterial concentrations in coastal recreational waters.

58 INDEPENDENT AND JOINT TOXICITY OF PERCHLORATE AND HEXAVALENT CHROMIUM TO LARVAL MOSQUITOES

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Perchlorate and hexavalent chromium are two anthropogenic pollutants found in ground and surface water in areas throughout Southern California, as well as elsewhere in the United States and in the world. In chronic exposure bioassays in the laboratory, perchlorate and hexavalent chromium were found to decrease survival and prolong development of larval *Culex quinquefasciatus* mosquitoes. The compounds were examined alone and in combination with each other. Perchlorate was found to have an LC50 of approximately 100,000 ug/L, while hexavalent chromium was found to have an LC50 of approximately 900 ug/L. These concentrations are within the range of levels reported from contaminated sites.

59 VARIATION OF JOSHUA TREE MORPHOLOGY AMONG POPULATIONS IN THE EASTERN MOJAVE DESERT

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The current distribution of *Yucca brevifolia* Engelm. (Joshua Tree) is restricted to specific habitats at higher elevations in the Mojave Desert. This distribution warrants investigation because it may represent the result of post-glacial migration and potentially restricted gene flow. The overall objective of our study is to reconstruct the phylogeography of *Y. brevifolia* based on morphological and genetic variances of populations in the Mojave Desert. Some taxonomic treatments of this species define more than one variety based on morphology. This includes *Y. brevifolia* var. *jaegeriana* (McKelvey, 1932), a variety of the Eastern Mojave defined by short, stout stems and short leaf lengths. In a preliminary study we examined the morphology of four populations in this region. The morphological variance of these populations was expected to be minimal, because they occurred relatively close to one another and within the described *jaegeriana* distribution. Trunk sizes and leaf lengths were compared among populations using ANOVA, and a broader evaluation was based on multivariate analyses of 13 tree and leaf traits. Tree sizes and leaf characteristics of three populations always conformed to the classification of var. *jaegeriana*; the fourth population (Garnet Mountain, AZ) showed characteristics of var. *jaegeriana* for leaf traits but not for trunk size. Principle components analysis revealed significant scatter among plants of all populations, but clearly separated the Garnet Mountain population from the rest. These results bring into question the varietal classifications of this species and suggest that environmental factors may cause closely related populations to show notable morphological difference.

60 ENDOCRINE DISRUPTION IN SOUTHERN COASTAL CALIFORNIA FLATFISH

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Some anthropogenic contaminants in the environment interfere with biological processes controlled by hormones, such as sex determination or growth. Previous studies indicate some endocrine disruption (ED) effects occurring in southern California marine fish living near municipal wastewater outfalls in Orange County, the Palos Verdes shelf, and Santa Monica Bay. To determine the extent of these ED effects in the Southern California Bight (SBC), three different flatfish species collected from different locales within the SCB are being studied through our collaborative efforts. This is a multi-year project that aims to develop rapid screening and quantitative assay methods for measuring the incidence of ED effects in marine flatfish. A microarray is being developed to screen the altered regulation of genes associated with endocrine activity. Additional assay methods are being used to validate the microarray results, including a vitellogenin ELISA, gonad histology and several immunoassays for endocrine factors. Our progress is discussed in terms of how this information is leading to a better understanding of the occurrence and magnitude of ED in SCB fish from reference locations and areas proximal to municipal wastewater discharges.

61 HPLC COLUMNS WITH MODIFIED MONOSACCHARIDE DERIVATIVES AS CHIRAL SELECTOR

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To meet the increasing demand for analyzing chiral pollutants, HPLC chiral stationary phases based on monosaccharide were prepared and evaluated. Monosaccharide D-galactose, D-glucose, D-mannose, D-galacturonic acid and D-glucuronic acid derivatives were coupled with aminopropyl or mercaptopropyl functionalized silica gel, and then modified by different groups on hydroxyl groups as chiral stationary phases. The columns were screened using an identical set of racemic compounds containing a variety of functionalities and the mixture of hexane and isopropanol as the mobile phase. Chiral separation was achieved for some compounds, but baseline separation was obtained only for binaphthol and 5,5′,6,6′,7,7′,8,8′-octahydro-1,1′-bi-2-naphthol. Hydrogen bonding interactions were supposed to result in their chiral separation. It was observed that the chiral resolution ability of monosaccaride derivative CSPs was weaker than that of polysaccharide CSPs. These results suggest that higher level structures of polysaccharide CSPs play an essential role in chiral separation. However, the well-defined monosaccharide HPLC stationary phases could provide valuable insight into chiral recognition mechanism for saccharide-based CSPs, which will be useful for finding and developing more effective CSPs.

62 BIOAVAILABILITY OF SYNTHETIC PYRETHROIDS IN SURFACE WATER

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Synthetic pyrethroids are widely used pesticides in both agricultural and urban environments. Most pyrethroids have high acute toxicity to fish and aquatic invertebrates. On the other hand, pyrethroids are known for their exceptional affinity to solids. In this study, we evaluated the effects of suspended solids in surface water on the bioaccumulation of two pyrethroid insecticides, bifenthrin and permethrin, to aquatic invertebrates. During the bioassays, we simultaneously exposed polydimethylsiloxane (PDMS) fibers as a "biomimetic" surrogate to measure the freely dissolved concentration of SPs in the test system. The concurrent analyses allowed understanding of the relationship between pesticide phase distribution and the measured bioconcentration factors (BCF) in water samples with different levels and sources of suspended solids. In all assays, the BCF consistently decreased with increasing suspended solids, suggesting that association with suspended solids reduced the bioavailability of pyrethroids. For instance, in samples containing 200 mg L^{-1} suspended solids from Miles Creek, uptake of bifenthrin by *Daphnia magna* decreased 65%. Simultaneous PDMS analysis revealed that the dissolved concentration of bifenthrin decreased by 52%. The effect of suspended solids on the bioavailability of pyrethroids was controlled by both the quantity and property of suspended solids. These results suggest that suspended solids in runoff effluents and surface water can decrease the bioavailability of pyrethroids to water-column invertebrates, and this phenomenon should be considered when evaluating the ecological risk and establishing water quality standards for pyrethroids.

63 STRAIN RELATEDNESS OF *CANDIDA* IN HUMANS: A URINARY PATHOGEN OR COLONIZER? (PHASE 1)

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Candida species in the urine of hospitalized patients (candiduria) is a very common occurrence among hospitalized patients with over 50,000 cases complicating hospitalizations annually. However, the clinical significance of candiduria remains controversial as there is evidence that this may represent a potentially serious and deadly infection that may spread to the bloodstream, or, alternately, merely represent urinary tract colonization. To resolve this, samples of urine from over 300 patients from Harbor-UCLA Medical Center were analyzed, and data regarding the patient's fungal infection or colonizations in different body sites, as well as their patterns of uses of antifungal medicines and urinary catheters were recorded. Differences in strains of each Candida infection (strain relatedness) were examined using traditional speciation methods as well as molecular techniques (DNA fingerprinting). The results of this experiment show that *Candida* in the urine commonly resolves spontaneously (97.4% or specimens) and can recur with either the same Candida strain (76.3%), or a different strain (23.7%). Furthermore, patients with Candiduria and Candidemia were more likely to lack strain relatedness (88.9%) than have strain relatedness (11.1%). Finally, antifungals did not have any effect on the persistence (3 days with versus 2.446 without treatments) nor the recurrence (2.67 recurrences with versus 2.53 without treatment) of fungal infections. Consequently, *Candida* in the urine among hospitalized patients does not appear to be associated with serious *Candida* bloodstream infections. Candiduria infectants tend to wax and wane with time, and occasionally are supplanted with other *Candida* strains. This suggests that most *Candida* strains have low pathogenicity in hospitalized patients and may not require treatment.

64 EFFECTS OF PHOSPHATE ON THE BIOLOGICAL PROCESSES OF TRICHODESMIUM

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The marine cyanobacterium *Trichodesmium* occurs throughout the tropical and subtropical oceans. These bacteria are unusual in their ability to convert atmospheric nitrogen into ammonium while undergoing photosynthesis and are responsible for the majority of the nitrogen supply in the open oceans. In exploiting their ability to fix nitrogen, the use of the oceans as a carbon dioxide sink can be maximized, helping to alleviate global warming. This research focused on the role of phosphate in the biological processes of *Trichodesmium* and its effect as a limiting nutrient. It is postulated that *Trichodesmium* has the ability to hydrolyze inorganic molecules to obtain an additional source of phosphorous, known as alkaline phosphatase activity (APA). This experiment tests *Trichodesmium*'s APA response in a variety of phosphate concentrations with an inorganic molecule, 4-methylumbelliferyl phosphate (MUF-P). An inverse relationship between the phosphate concentrations and the amount of MUF-P hydrolyzed was found, confirming the theory that the cyanobacterium has the ability to provide itself with additional phosphorous, should the need arise. The experiment also analyzed the relationship between the concentration of phosphate available and the nitrogen fixing ability of *Trichodesmium.* Using the acetylene reduction process, a direct relationship between the two components was found, verifying the role of phosphate as a limiting nutrient. A better understanding of the role that phosphate plays in maintaining a elemental balance in the open oceans is essential in implementing the use of the oceans as a biological sink for carbon dioxide, thus lessening the major threat that global warming currently presents.

65 DETERMINATION OF BACTERIAL AND POLLUTANT FLOWS IN COASTAL ESTUARIES OF SOUTHERN CALIFORNIA

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There are two main objectives of this experiment: to create a mathematical model showing the relationship between turbidity, dissolved oxygen, pH, salinity, time from high tide, and levels of indicator bacteria for fecal contamination and to assess the impact of the Ballona Wetlands on coastal ocean waters. In the field samples were tested for temperature, dissolved oxygen, salinity, and pH levels using the YSI 600R Sonde Electronic Probe. Further testing was done in the lab using the HACH 2100N Turbidimeter for turbidity levels and IDEXX Quantitray 2000 System with the MPN method for levels of indicator bacteria. A mathematical model was created showing the relationship between dissolved oxygen (DO), turbidity (T), pH, salinity, time from high tide, and bacterial growth (EB), where K is the constant of proportionality, and d, a, and b are constants.

$$EB = K\frac{e^{[(-|7\,-\,pH|)+DO+Sal]}[\cos(2\pi t/\beta) + d]}{1 + ae^{(\ bT)}}$$

E. Coli: K = 1.09 × 10^{34}; d = 85.0; a = 7.10; b = 4.77

Enterococci: K = 1.90 × 10^{-1}; d = 30.0; a = 2.49; b = 4.77

Results indicated that bacterial levels were higher with decreased dissolved oxygen, decreased salinity, and increased turbidity in a neutral pH. Bacterial levels were also higher at and around high tide. This study shows that sophisticated mathematical models can be constructed to greatly simplify the current testing procedures and be more cost-effective. This model will prove critical from an economic point of view and from beach safety considerations.

66 NEAR REAL-TIME DETECTION OF *ESCHERICHIA COLI* FOR MONITORING BEACH WATER QUALITY

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Currently used methods for detecting fecal indicator bacteria in recreational water require 18–24 hours for sample analysis. Because this poses obvious problems for safeguarding public health, real-time methods for FIB and pathogen detection in environmental waters need to be developed and tested. We are adapting for use in marine waters a recently developed method for near real-time *E. coli* detection based on immunomagnetic separation and quantification of ATP using luciferin/luciferase. We have documented levels of ATP (in RLU units) per cell in a lab culture of *E. coli* during the lag, exponential, and plateau phases of the growth curve. Good calibration curves were attained at each growth phase; however, the level of ATP per cell in the *E. coli* population was observed to be a function of its growth phase. We are comparing the near real-time method with membrane filtration and IDEXX, a standard technique currently used extensively in Southern California for monitoring recreational water quality.

67 INDIVIDUAL AND JOINT EFFECTS OF SELENATE AND METHYLMERCURY ON A TERRESTRIAL INSECT DETRITIVORE

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Although insects play crucial roles in most ecosystems, surprisingly little is known about how anthropogenic pollutants or their mixtures affect insect populations. In this study we investigated the individual and combined effects of selenate and methylmercury on the larval stage of a ubiquitous insect detritivore *Megaselia scalaris.* We found that females did not avoid depositing eggs on food sources contaminated with either selenate or methylmercury. However, larval survival was significantly decreased and larval development was significantly prolonged by selenate and methylmercury individually at low or intermediate treatment levels that are ecologically relevant. In addition, potentiation was strongly evident as mixtures containing concentrations as low as only 1% of the respective individual LC_{50}s caused significantly more mortality and delayed larval development than would be expected from the responses selenate and methylmercury elicit individually. Indeed, the relative toxicity to *M. scalaris* of each of the individual and joint treatments was selenate ($LC_{50} = 260$ μg/g) < methylmercury ($LC_{50} = 22$ μg/g) < mixture ($LC_{50} = 13$ μg/g of selenate plus 1.1 μg/g of methylmercury). The increased mortality and delayed larval development within sites contaminated by selenate, methylmercury, or the combination, have substantial implications for the ecology, population dynamics, and sustainability of *M. scalaris* populations. If these results can be extrapolated to other arthropod detritivores, ecosystem food-web function may be substantially affected.

68 HEAVY METALS IN THE CLAM *MEGAPITARIA SQUALIDA* FROM APPARENTLY POLLUTION-FREE ZONES IN BAJA CALIFORNIA, MEXICO: CONSIDERATIONS FOR HUMAN HEALTH EFFECTS

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Bahía de La Paz, a bay within the Gulf of California, has been traditionally characterized as free of industrial sources of pollution and having a population density low enough to avoid serious problems. The "chocolate clam" *Megapitaria squalida,* is widely consumed by the population of several localities along the Pacific coast. Clams collected from seven stations located in Bahía de la Paz, before and after the summer rainy season were analyzed for Cd, Ni, Cu, Mn, Pb, Fe, and Zn. The location of the sampling sites significantly affected the concentration of metals in clam tissues, but not in relation to the proximity to alleged contaminated sites. Clams from a site close to a phosphate mine had the highest levels of Pb, but only in April, and the highest concentrations of cadmium were recorded in clams collected in areas without any anthropogenic activities. Clams from a sites considered clean had higher levels of Cd, Fe, Zn, and Mn. The mean concentrations (μg/g dry weight) ranged from 1.5 to 11.1 for Cd, 1.9 to 8.8 for Ni, 5.4 to 18.7 for Cu, 2.5 to 9.3 for Mn, 0.06 to 7.8 for Pb, 154 to 558 for Fe, and 47.2 to 64.6 for Zn. Based on the results obtained in this study, the consumption a regular meal of 200 g of clam tissue does not represent a risk for human health and proportion a good source of essential elements.

69 SUSCEPTIBILITY OF OXIDATIVELY CROSSLINKED β-AMYLOID PEPTIDES TO INSULIN DEGRADING ENZYME

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Amyloid-Beta protein (AB) plays an important role in the pathogenesis of Alzheimer's disease and is thought to be the cause of neuronal deaths. Oxidized AB and oxidatively crosslinked were examined to see if they were less susceptible to protease digestion by insulin-degrading enzyme (IDE), a major

AB degrading enzyme and compared digestion by the more general protease, trypsin. AB40 and AB42 peptides were each oxidized with either NBS or CU/H2O2. Oxidized AB40 and AB42 lyophilized and resuspended and then desalted using C18 spin columns. They were then assayed using BCA protein method to determine the recovery of AB from the columns. Non-oxidized and oxidized AB40 and AB42 were subjected to proteolysis with IDE or trypsin and then were electrophoresed and analyzed by Western blot. Results have shown that trypsin is able to degrade unoxidized AB40 and AB42 but is unable to digest oxidized samples of AB. IDE was only able to digest partial amounts of unoxidized and oxidized AB. This is a deviation from previous research which has shown that IDE is able to fully degrade unoxidized AB. Further research may be continued to determine whether there may be inhibitions in IDE's abilities to degrade AB due to oxidation.

71 THE HISTORY OF WILDLAND FIRES IN AMERICA

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Fire was a common tool used by pioneers, loggers, farmers, and ranchers prior to 1900. Natural ignitions burned uncontrollably. Promiscuous and careless uses of fire lead to restrictions shortly after 1900. The Smokey-the-Bear anti-fire campaign and propaganda was so effective that by 1940 burning in America was virtually shut down. Burning persisted in only a few local areas, labeled "backward" by the Government. Starting in 1960, ecological studies began to document the natural role of fire in various wildlands and to question U.S. policies of putting out all fires and labeling all fires as bad. By 1980 controlled burning was becoming commonplace and plans were being made to let some lightning ignitions burn. Most federal and state agencies dealing with natural resources had developed prescribed burning guidelines. The movement to restore the natural role of fire suffered a setback with the massive 1988 Yellowstone wildfire. Questions of liability, inability of burners to obtain insurance, and lack of confidence and skill, and concerns about costs, budgets, limited burning opportunities, and other bureaucratic red tape began to delay burning. As a result, the restoration of fire to appropriate ecosystems in their natural sequence continues to be inadequate. This is particularly true in southern California where chaparral occurs on steep terrain and is juxtaposed on urban development. Meanwhile, the payback of a century of fire exclusion continues with one record-breaking wildfire after another, year after year!

72 ECONOMIC IMPACT OF WILDLAND FIRES

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A recent international symposium on fire economics held in Córdoba, Spain highlighted many of the common concerns with the problems of wildland fires throughout the world. Some of the most prominent reasons presented for the continuous and increasing wildland fire problem were related to social and economic factors such as poverty in rural areas, particularly in developing countries economies, and land abandonment of the rural areas in Europe. A related problem, and possibly the most prominent here in California, is the population increase and higher concentrations along forested areas, creating the new coined problem of the wildland urban interface (WUI).

It was evident from regional presentations at the symposium that the costs associated with the wildland fires problem and fire management programs are substantial ranging in the billion of dollars. For example, since 2000, the United States Department of Agriculture Forest Service (USDAFS) alone has spent more than $1 billion annually in forest fires suppression. Canada spends and average of $400 to $800 million annually. Neither of these figures includes timber, health, recreation or personal property related expenditures. In the South American continent losses are estimated as high as $1.6 billion annually. Recent estimates of the impacts of the Indonesian fires of 1997 on the economies of Indonesia, Malaysia, and Singapore were as high as $4.5 billion. Closer to home, in 2003, in California alone, 750,043 acres were burned, 3,710 homes destroyed, 24 lives lost, and more than $3.5 billion in property losses!

73 POST-FIRE EROSION IN THE SAN GABRIEL MOUNTAINS

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Wildfire is a significant disturbance event that promotes accelerated erosion in upland watersheds. This accelerated erosion can cause environmental site degradation and may threaten life, property, and infrastructure in human communities downstream at the wildland/urban interface. Management treatments following a wildfire in 1960 involved the vegetation type-conversion of some native chaparral watersheds to a mixture of perennial grasses on the San Dimas Experimental Forest (SDEF) in the San Gabriel Mountains. In September 2002 virtually the entire SDEF burned again in the Williams Fire, including several small (2–3 ha) headwater catchments in both brush and grass fuel types. Hillslope erosion was measured in 30 cm aperture sediment collector traps. Pre-fire erosion was 10 times greater under native chaparral than on grass hillsides. Compared to pre-fire erosion, first year post-fire hillslope erosion was ten times greater under brush vegetation and over 100 times greater under grass. Prescribed fire produced less erosion than wildfire on comparable chaparral hillsides. Small watershed sediment yield was measured in reservoirs behind debris dams. Prior to burning, sediment yield in both grass and chaparral watersheds was small, and varied with annual rainfall. After the wildfire, large amounts of sediment were delivered to the reservoirs under moderate rainfall, regardless of vegetation type. Prescribed fire produced less sediment yield than wildfire in comparable chaparral watersheds. Although accelerated erosion and sediment yield after burning appears to be inevitable, prescribed fire may be an effective sediment management tool.

74 NEW TRICKS ON THE OLD FIRE

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The Old Fire will not soon be forgotten by Southern California firefighting agencies. In October 2003, it burned over 90,000 acres, 940 homes, and 30 commercial structures. It resulted in six fatalities, and contributed to a deadly flash flood in Waterman Canyon two months after the fire. The Old Fire also was the first time that an integrated weather/fire behavior modeling system was used to predict the fire's growth on a daily basis. This presentation describes the weather modeling (MM5), fire behavior modeling (FARSITE), and fire imaging (FireMapper™) technologies that provide a powerful array of tools for wildland fire science and management.

75 STRATEGIC FIRE MAPPING–TECHNOLOGY DEVELOPMENT FOR AIRBORNE REMOTE SENSING OF WILDLAND FIRES

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A new airborne thermal-imaging radiometer, the FireMapper®, has been developed by the Pacific Southwest Research Station (PSW) and Space Instruments, Inc, for strategic fire mapping and to improve fire suppression operations, fire-fighter safety, and our understanding of the behavior and environmental impacts of wildland fire. Based on night-vision technology developed by the U.S. Department of Defense, FireMapper measures thermal radiation from spot fires and intense flaming fronts alike; resulting estimates of ground-surface temperatures provide a measure of the intensity and progress of wildland fires. The FireMapper was deployed during the fire emergency in California during 2003 aboard PSW's Airborne Sciences Aircraft, N70Z, a twin-engine Piper Navajo. Data were uplinked by satellite communication, geo-referenced to a map base, and posted to the Internet at *www.fireimaging.com* for use by fire operations. Best delivery time to the Internet was 90 minutes. The PSW system has now been improved with an advanced inertial navigation system and satellite communications with a goal of delivering data to the Internet in less than one-half hour. Next-generation FireMapper 2.0 instruments have also been engineered and put into use aboard N70Z and N30W, an Aerial Supervision Module operated by the Bureau of Land Management.

76 CHANGES IN SPATIAL DISTRIBUTION AND ABUNDANCE OF BIRDS IN RELATION TO FIRE AND DROUGHT-INDUCED VEGETATION MORTALITY IN SOUTHERN CALIFORNIA

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Avian community changes were studied in relation to fire history and a severe drought in a Mediterranean ecosystem in the San Jacinto Mountains in southern California for five years pre-drought (1997–2001) and a planned five years post-drought (2004–2008). Plots were established in mixed oak, mixed conifer, and mixed chaparral vegetation types. Bird surveys were conducted on 87 variable circular plots during migration and breeding periods (March–June) using trained observers for five minutes between 0600 and 1030. Vegetation was measured at two sites on each bird plot. Habitat data included tree age (based on cores and fire history), height, dbh, canopy cover, shrub cover, and herbaceous cover. We used a geographic information system (GIS) and logistic regression to predict and map the pre-drought spatial distribution of birds. Resident granivorous and insectivorous birds were most likely associated with old growth (> 50 years since last burn) chaparral stands. Migratory insectivorous birds were associated with mixed oak woodlands adjacent to water and patches of mixed conifers. First year results of the post-drought data indicate increases in relative densities of resident birds in plots with high drought-induced tree mortality and no changes in relative densities of migratory birds in those plots. These preliminary analyses suggest that fire and drought related vegetation mortality are not necessarily detrimental to avian communities and have mixed effects on these communities.

77 THE CONTRIBUTION OF FOREST INSECTS AND PATHOGENS TO TREE MORTALITY IN SOUTHERN CALIFORNIA MONTANE FORESTS

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A severe multi-year drought in southern California caused extensive vegetation mortality which peaked in 2003. That September aerial surveyors mapped woody vegetation mortality above 1% (background) on 522,000 acres of a total of 819,000 acres on the San Bernardino National Forest. Woody vegetation mortality of above 10% was observed on 450,000 acres. In some areas pine mortality approached 100%. The Peninsular Ranges of San Diego Co. experienced similar levels of mortality, while less mortality occurred in the Transverse Ranges west of the Cajon Pass. Pine forests were especially affected because of an outbreak of native bark beetles, in particular, *Dendroctonus brevicomis, D. ponderosae,* and *D. jeffreyi.* These bark beetles kill pines that might otherwise survive drought. Air pollution injury and plant diseases, especially *Heterobasidion annosum* and *Arceuthobium* spp., contributed to tree stress, facilitating successful colonization by bark beetles. Less aggressive insect pests, particularly *Ips* spp., *Scolytus ventralis,* and *Melanophila californica,* killed trees not colonized by more aggressive insects. In 2004 pine mortality and the population of *D. brevicomis* declined for unknown reasons. Bark beetle populations are expected to drop further because of above average precipitation this winter. Public and private landowners responded to the mortality by removing dead trees to reduce hazardous fuels around communities. Long term effects of the mortality are unknown, but include lengthy recovery times for some ecosystems (e.g., single leaf pinyon in the Santa Rosa Mountains), probable increase in *H. annosum* infection centers, and possible species and genetic shifts associated with forest regeneration and replanting.

78 WILDFIRE AFFECTS SOUTHERN CALIFORNIA RIPARIAN HABITAT

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In June 2002, two wildfires (Louisiana and Blue Cut) burned over 13,000 acres, including important riparian habitat along Cajon Creek near Cajon Pass, San Bernardino County, CA. Cajon Pass is a heavily used corridor with freeways, trains, and utilities that run alongside and bridge Cajon Creek. This and adjoining perennial drainages are used for recreating and are channeled for flood control. Natural processes are thus disrupted, and the distribution and range of many species is constrained. Sections of Cajon Creek were denoted suitable habitat for three federally listed species—arroyo toad (*Bufo californicus*), least Bell's vireo (*Vireo bellii pusillus*), southwestern willow flycatcher (*Empi-*

donax traillii extimus); and one forest sensitive species—Santa Ana speckled dace (*Rhinichthys osculus*). After the fires, all burned trees near the railroad bridges that crossed Cajon Creek were cut. We initiated a study to determine how fire and tree removal affected the riparian habitat for the native species. We sub-sampled vegetation with line transects running across the creek in unburned, burned, and burned and cut areas. Tree removal reduced recovery rate of burned area vegetation for both height and percent cover. Burned area shrubs and herbaceous plants benefited from the reduced overstory. Rapid recovery of suitable habitat for fauna was observed, but vertical dimensions were still below pre-burn measures 2 years later. Post-fire bird surveys revealed continued use of the riparian area, and Santa Ana speckled dace were observed in Cajon Creek. Many species using this riparian area demonstrate remarkable resilience to fire and post-fire disturbances.

79 SAN DIEGO FIRE RECOVERY NETWORK: WORKING AND LEARNING TOGETHER

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The October 2003 wildfires were unprecedented for San Diego—with 16 deaths, 2600 homes lost, and 390,000 acres blackened. We were awed by the power of wildfire, by the personal and community losses, by nature's resilience and recovery, and by the reality that we are "between fires" in these Mediterranean and semi-arid ecosystems. Less than a week after the October 2003 wildfires began, the San Diego Fire Recovery Network was formed, holding meetings at the San Diego Natural History Museum. This open network has representation from more than 100 scientific and community organizations, and public agencies working together to foster the recovery of our human and natural environment through sound science, public education, land and community restoration. More than 400 professionals have attended one or more of the workshops and meetings on fire ecology of chaparral; fire ecology of San Diego's forests; "firesafe" construction and "firewise" landscaping; and post-fire watershed recovery. Professionals, volunteers and students worked together on wildlife surveys through the San Diego Mammal Atlas and Bird Atlas, wildfire education videos, the *Earth, Wind & WILDFIRE* exhibition at the San Diego Natural History, community fire plans, and more. In cooperation with the US Forest Service Riverside Fire Lab, four interdisciplinary workshops will be held in June 2005 across southern California to help define the socioeconomic and political gaps in reducing wildfire risks in chaparral ecosystems while sustaining native habitats, biodiversity, and watersheds as wildland-urban interface and exurban development accelerate.

80 HOW ISLAND SCRUB-JAYS ATTAIN BREEDING STATUS IN LIMITED HABITAT

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The Island Scrub-Jay, *Aphelocoma insularis,* is an endemic resident of Santa Cruz Island. Earlier studies have shown these birds to be permanently territorial and monogamous. Young birds generally take three or four years to obtain a territory. The most common method is for a pre-breeder to replace a member of an established pair upon the death of an adult of either sex. Other documented methods include usurping a territory upon the death of one breeder, amalgamation of adjacent territories and divorce and re-pairing of older breeders. Whatever the method utilized, obtaining a territory or becoming part of a territorial pair is prerequisite to becoming part of the breeding population

81 POPULATION GENETICS OF PYGMY NUTHATCHES IN SOUTHERN CALIFORNIA

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We sequenced 1639 base pairs of mitochondrial DNA to examine the distribution of genetic variation among pygmy nuthatch (*Sitta pygmaea*) populations in southern California. Pygmy nuthatches are small songbirds resident in coniferous forest throughout western North America; they occur in the mountains of southern California as disjunct sky island populations. In order to determine the extent of gene flow among these disjunct populations, we used portions of cytochrome *b,* ND6, and the control region to characterize the genetic differentiation within and among mountain ranges, as well as between the 2 subspecies (*S. p. melanotis* and *S. p. leuconucha*) that occur within the study area. Analysis of 75 individuals from 11 collecting locations in 7 mountain ranges yielded 17 haplotypes.

Measures of genetic distance were low among both haplotypes and populations (mountain ranges). Phylogenetic analyses showed strong support for several haplotype clades. These clades, however, appear only weakly correlated with geography. The overall F_{ST} for mountain range comparisons was relatively low but significant, indicating the presence of some genetic structure. Additionally, a Mantel test based on collecting locations revealed a significant isolation by distance effect. Results from AMOVA suggest weak but significant genetic differentiation between *S. p. melanotis* and *S. p. leuconucha,* with the restriction of gene flow occurring between the Transverse and Peninsular Ranges. Overall, these results indicate that gene flow is restricted among southern California pygmy nuthatch populations, but that these populations are recently diverged.

82 SEASONAL AND INTERANNUAL MOVEMENTS OF SALTON SEA- HATCHED BLACK SKIMMERS (*RYNCHOPS NIGER*)

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Over 2570 pre-fledging Black Skimmers (*Rynchops niger*) have been banded at the Salton Sea in southeastern California between 1991 to 2004; nearly all of these were given additional alphanumeric or color bands to identify individuals or cohorts. Our re-sighting efforts in coastal California and western Mexico during the non-breeding season have yielded important information on migratory movements and suggest considerable interconnectivity of breeding populations throughout the region. Of the 937 skimmers banded at the Sea in the years 1999 to 2001, 275 birds have been re-sighted at least once. Of 62 of these birds re-sighted during the first winter after fledging, 37 (60%) were along the Pacific Coast of California or northwestern Baja California and 25 (40%) were in the Gulf of California or the mainland west coast of Mexico. Analysis of the remaining re-sighting data shows a complex set of outcomes, with some birds that disperse to the Pacific Coast remaining there to breed, but others returning to breed at colonies at the Salton Sea or Colorado River delta region. Most birds dispersing to the Gulf and western Mexico remain to breed in the Salton Sea/Gulf region (south at least to southern Sonora), but some have appeared at coastal California colonies. Furthermore, some birds banded as pre-fledglings in coastal California colonies have wintered on the west coast of mainland Mexico and in a few cases have subsequently been re-sighted at Salton Sea breeding colonies.

83 OVER-WINTERING BEHAVIOR OF BLACK SKIMMERS IN SOUTHERN CALIFORNIA: SITTERS AND WANDERERS

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The Black Skimmer is a recent, but now well established, breeding species in southern California. A large portion of the coastal population, augmented by birds from the Salton Sea colonies, now overwinters at 3–4 local sites. Although these sites are regularly used by skimmers year after year, site fidelity of individual birds is highly variable. Some individuals have been regularly, if not always, found at only one site winter after winter. Others move between sites, even one or more times within a single winter season. The causes for these contrasting behaviors are not readily apparent although adverse weather conditions may play a role in some cases.

84 AVIAN EXTIRPATION AND COLONIZATION IN THE BALLONA VALLEY, LOS ANGELES COUNTY, CALIFORNIA

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Successful ecological restoration depends on a clear understanding of the history of local species loss and colonization. One area of California where this can be uniquely achieved is the Ballona Wetlands, one of the best-studied coastal habitats in the state, recently acquired for restoration and protection as a proposed Ecological Reserve. Though birds are among the primary beneficiaries of this effort, the avifauna of Ballona has not been critically examined in more than 60 years. Drawing from historical and current records, I identify 40 taxa that have been extirpated from the wetlands in one or more role since 1900. Of these, 11 have subsequently become reestablished as regular nesters or winterers after an absence of several decades, and 19, including four non-native taxa, have apparently colonized in one or more roles since the mid-1900s. I analyze this turnover in terms of three major periods of local habitat change, including stream-channelization; wetland draining and creation; agricultural expansion and decline; urban expansion; the construction of a massive marina; and the spread of non-native plant and animal species. This research should facilitate the development of target species to be monitored as the system is restored

85 CHANGES IN BIRD SPECIES DIVERSITY FOLLOWING A SALTMARSH RESTORATION PROJECT AT BATIQUITOS LAGOON

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Batiquitos Lagoon is located in the City of Carlsbad, north San Diego County. Once a tidal system, it was largely non-tidal for 90 years, prior to a $60 million lagoon restoration project conducted from 1994 through 1996 as a mitigation project by the Port of Los Angeles. Following restoration, a long-term biological monitoring program was initiated. It included surveys for vegetation, fish, benthic infauna and birds in years 1, 2, 3, 5, and 10 following lagoon restoration. Avian surveys were performed quarterly during those years to document the changes in bird usage following construction. During 1998 and 1999, mudflat habitat supported the highest densities of birds during all quarters. This was a change from 1997, when shallow water and open water supported substantially higher densities of birds, and was due to development of mudflats within the lagoon following construction. Other changes in bird habitats, species diversity, overall bird numbers, bird guilds, and populations of special-status species at the lagoon observed during surveys conducted in 1997, 1998, 1999 and 2001 will be discussed.

86 SPECIAL STATUS BIRDS OF THE WHITTIER NARROWS BASIN, LOS ANGELES COUNTY

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The 1500 acre Whittier Narrows Recreation Area and adjacent San Gabriel River and Rio Hondo Rivers in South El Monte supports a remarkable diversity of bird species. A total of 293 bird species (298 species and subspecies) has been recorded in the area through April 2005. Particularly important to birds is the presence of year-round surface water in the form of ponds, lakes and streams and the associated riparian vegetation. Analysis of over forty years of records resulted in the publication of the first comprehensive, annotated work on bird species occurrence and seasonal use of the area (currently under revision). The area supports over fifty Special Status bird species (some seventy species from the State Special Animals List have occurred) such as Least Bittern and Least Bell's Vireo, and these are highlighted as to seasonal distribution and breeding status. Recent changes in the status of several species, such as establishment of heron and cormorant rookeries and nesting yellow warblers, and current land use conflicts and management difficulties are briefly discussed.

87 POPULATION STATUS OF ROYAL TERNS IN SOUTHERN CALIFORNIA

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The Royal Tern, *Sterna maxima,* is an abundant seasonal breeder on the Atlantic and Gulf coasts. On the Pacific coast, however, it is decidedly less common, with perhaps fewer than 100 pairs currently breeding in California. This is very different from the situation 50 years ago when it was one of the commonest large terns in this area. Its decline and recovery (?) seems related to a similar decline (and recovery?) of a favorite inshore prey item, the Pacific Sardine, *Sarninops sayax.* Adult annual survival is high (>88%), as is true of other tern species, and the local breeding population seems to be increasing, albeit slowly.

88 POPULATION STATUS OF THE CALIFORNIA LEAST TERN

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The California least tern (*Sterna antillarum browni*) breeds from April through August at nesting areas along the coast from the San Francisco Bay, California to lower Baja California, Mexico. Prior to its listing as endangered under both the federal and California Endangered Species Act in the early 1970's, the progressive conversion of suitable nesting habitat to human uses had resulted in a severe reduction in both nesting sites and numbers of nesting pairs. Thereafter, the number of nesting pairs in California escalated from an estimated 664 in 1976 to over 6,000 in 2004, and up to 38 nesting sites are now used, up from 23 in 1976, when statewide censuses were initiated. However, over 80% of the nesting population is concentrated in 10 sites. In addition, poor production years such as 1999 still threaten the population, as does predation by a variety of both native and non-native predators. Thus, continued management will be required to ensure long-term survival. Population and productivity fluctuations, existing management and monitoring methods and recommendations for future monitoring and management will be discussed.

89 LEAST BELL'S VIREO IN THE SANTA ANA RIVER WATERSHED

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At one time considered common, the least Bell's vireo *Vireo bellii pusillus* was widely distributed throughout the Central Valley and other low elevation riverine systems of southern California and Baja California, Mexico. However, by the mid-1900s habitat loss due to agricultural, urban, and commercial developments, flood control and river channelization projects, livestock grazing, and other activities had severely reduced the available habitat and the vireo was extirpated from much of its former range. Nest parasitism by brown-headed cowbirds *Molothrus ater* greatly limited the vireos' reproductive output and in concert with habitat loss, vireo numbers plummeted. When the vireo was finally listed as endangered in 1980, there were only 300 pairs known to exist throughout the historic range.

Orange County Water Districts' vireo management program began in 1986 when 21 territories and 19 pairs were documented. Nineteen nesting seasons later in 2004 there were 590 vireo territories found in the Prado Basin. The efforts in the basin have been mirrored outside the basin throughout the watershed since 2000 by the District and its partners in the Santa Ana Watershed Association (SAWA) and an additional 249 vireo territories were observed on the river and tributaries in 2004. Thus, the Santa Ana River held a minimum total of 837 territories in 2004 compared to 824 territories on Camp Pendleton.

The expansion of the vireo population on the Santa Ana River was achieved by dedicated field staff adaptively managing natural resources. The significance of this achievement is that it happened on a river system that has been greatly altered by human activity and has been dramatically narrowed and heavily urbanized to its very edges. It demonstrates that consistent wildlife management works for some species.

90 POPULATION STATUS OF THE WESTERN GULL-BILLED TERN (*STERNA NILOTICA VANROSSEMI*) IN NORTH AMERICA

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The Western Gull-billed Tern is a highly localized breeder, nesting at just a handful of locations in California and western Mexico. In California, the tern forms small nesting colonies at only two locations, the Salton Sea and south San Diego Bay. Gull-billed Terns colonized the Salton Sea by the late 1920s, but the colony in San Diego Bay was not established until 1986. Until recently, a lack of information on breeding locations in western Mexico has hampered efforts to estimate the total population size for this subspecies; the only known colonies were in the Colorado River delta region (Cerro Prieto and Isla Montague) and Bahia Santa Maria, Sinaloa. Surveys in Mexico in 2003 by Palacios and Mellink documented the existence of four previously unknown breeding locations, one in Baja California Sur, two in Nayarit and one in Colima, bringing the number of colony sites in Mexico to seven. Colony sizes are generally small but ranged from 2 to 200 pairs. Results of simultaneous surveys in California and western Mexico in 2003 suggest that the entire breeding population of the Western Gull-billed Tern consists of fewer than 600 pairs. The expected degradation of habitats at the Salton Sea as a result of reduced freshwater inflows and proposed urban development, and conflicts with listed species in San Diego threaten the viability of this species in California.

91 POPULATION STATUS OF LIGHT-FOOTED CLAPPER RAIL

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The Light-footed Clapper Rail (*Rallus longirostris levipes*) is a State and Federally listed endangered species that is resident in coastal wetlands in southern California and northern Baja, California, Mexico. Loss and degradation of habitat threaten the continued existence of this bird, although management efforts now offer some promise of recovery.

The twenty-fifth annual census of the Light-footed Clapper Rail in California was conducted from 23 February–23 May 2004. Thirty coastal wetlands were surveyed by assessing call counts from Carpinteria Marsh in Santa Barbara County, south to Tijuana Marsh National Wildlife Refuge (NWR) on the Mexican border.

A total of 350 pairs of Light-footed Clapper Rails exhibited breeding behavior in 15 marshes in 2004. This is the largest statewide breeding population detected since the counts began in 1980, representing an 8% increase over the former high in 1996 and a 22% increase over the 2003 total. Upper Newport Bay and Tijuana Marsh NWR were at all-time highs, together supporting 44 pairs more than in 2003. The Newport subpopulation comprised 47.1% of the state population in 2004 and together with the subpopulation in the Tijuana Marsh NWR totaled 252 pairs, or 72% of the breeding population of this rail in California.

The subpopulation at Point Mugu is now the third largest in the state with 19 pairs. Although the Seal Beach tally continued to decline, 5 of the other small subpopulation were at record or recent highs. Most notably, the Kendall-Frost Reserve supported 14 pairs and there were 11 pairs in Batiquitos Lagoon and 6 pairs in the San Dieguito River Valley.

Excluding the 4 largest subpopulations, the remaining 11 totaled 63 breeding pairs of clapper rails, 18% of the state total. The rebounding of several of the small subpopulations gives reason to believe that restoration and management can work for the Light-footed Clapper Rail.

92 THE STATUS OF WESTERN SNOWY PLOVERS IN COASTAL SOUTHERN CALIFORNIA

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Historically, coastal Southern California supported one of the largest breeding and wintering populations of Western Snowy Plovers (*Charadrius alexandrinus nivosus*) along the Pacific Coast. Human population growth and easy access to beaches has resulted in most historical snowy plover breeding habitat being converted to recreational uses. Today, breeding Western Snowy Plovers are distributed among four major sites in coastal southern California: Bolsa Chica Ecological Reserve, the Santa Margarita River mouth, Batiquitos Lagoon, and the Silver Strand on the west side of San Diego Bay from Coronado to the U.S./Mexico border. Based on the results of a population viability analysis, the recovery goal for southern California is 500 breeding adults. The 2004 breeding season window survey counted 281 breeding adults in the region, which is likely an underestimate, but continues a five year trend of increasing numbers. Wintering numbers have increased slightly over the past five years, with the largest wintering flocks located at Zuma State Beach, the Santa Margarita River mouth, the Silver Strand, and the Tijuana River mouth. Winter totals have increased from 833 birds in 2003, to 847 in 2004, to 894 in 2005. The major limitations to population growth include nest predation and lack of suitable breeding habitat. Efforts to restore beach habitat are underway but are constrained by the intense recreational uses of beaches year round and beach raking that removes foraging and breeding habitat.

93 DIETARY RESPONSE OF THE ELEGANT TERN (*STERNA ELEGANS*) TO CHANGING OCEAN CONDITIONS AND PREY POPULATIONS IN SOUTHERN CALIFORNIA

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We compared the diets of Elegant Terns at three nesting sites in southern California in 2004 to help determine whether ocean conditions have shifted from a warm to a cool regime since 1999 and therefore whether this abundant seabird can indicate oceanographic regime changes. Previous studies have shown that the northern anchovy is a major prey species for this tern, but during warmer years the Pacific sardines can become a more important prey species. If the ocean is now in a cool regime, we expected a higher anchovy to sardine ratio in this tern's diet at all three sites, but more pronounced at the two northerly locations (Los Angeles Harbor and Bolsa Chica Ecological Reserve). We also expected Elegant Terns to have a broader diet at the more southerly site (San Diego Salt Works) because of a subtropical influence. Diets were assessed by identifying fish dropped by the birds or regurgitated by the young during parent-chick feeding encounters at the colonies. The anchovy to sardine ratios from the Los Angeles and Bolsa Chica samples were significantly larger than the San Diego site. Prey composition, but not prey diversity, also differed significantly among sites. Based on a Pacific Decadal Oscillation (PDO) index, dietary species composition from 1993 to 2004 at Bolsa Chica differed significantly between years of cooler and warmer conditions. Our work to date shows apparent influences of climate on prey availability and Elegant Tern diet in the region, but we are continuing our analysis to resolve the picture.

94 GAS EXCHANGE RESPONSES TO PULSE RAIN EVENTS BY A NATIVE HAWAIIAN DRY FOREST VINE AND THE EFFECT OF INTERACTION WITH NON-NATIVE GRASSES

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The dry forests of Hawaii have experienced reduced seedling recruitment since invasion by *Pennisetum setaceum,* a C_4, perennial bunch grass native to Africa. Precipitation in these forests is spatially and temporally variable at the seasonal and annual scales. In a common garden experiment we examined the use of pulse rain events by seedlings of *Canavalia hawaiiensis* a vine native to the Hawaiian dry forest. *Canavalia* seedlings (grown with and without the presence of *Pennisetum*) received simulated pulse rain events of five sizes and their gas-exchange responses were monitored. Plants responded to water pulses of as little as 5 mm, but at least 20 mm was required for a lasting ($\geq$3 day) response. However, in the presence of *Pennisetum,* responses were lower and shorter lived, suggesting that in the presence of the *Pennisetum* additional water input is required for the gas exchange plateau to be reached. These results suggest that the reduction of native seedling recruitment can partly be explained by altered resource dynamics, specifically pulse moisture utilization, due to invasion by *Pennisetum.*

95 BORN AND RAISED IN SOUTHERN CALIFORNIA: DEVELOPMENTAL EVOLUTION AND CRYPTIC SPECIATION IN THE SEA SLUG GENUS *ALDERIA*

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Variable development within a single species (poecilogony) is a rare phenomenon, and putative examples often comprise cryptic species. The sacoglossan genus *Alderia* contains a single recognized species in north Atlantic and Pacific estuaries; it produces feeding larvae (planktotrophy) throughout its distribution except in California, where both planktotrophy and lecithotrophy (non-feeding larvae) are expressed. Molecular, morphological and developmental evidence indicate that populations south of Bodega Harbor comprise a true poecilogonous species, distinct from the strictly planktotrophic congener *A. modesta.* Northern populations (Bodega to Vancouver) consist of large adults with a smooth dorsum that produce planktotrophic larvae; those from Tomales Bay south consist of smaller adults with a raised dorsum that seasonally toggle between planktotrophy and lecithotrophy. Sequences of the mitochondrial cytochrome oxidase I gene were obtained from 204 individuals from 14 populations. Northern and southern haplotypes formed reciprocally monophyletic clades differing by 16–20%, including fixed differences at 36 of 480 sites. Molecular clock calibration indicates the species have diverged since the early Pleistocene (1.4 million years ago). The northern species is absent from the south of Tomales Bay yet common only 4 km away, and was rare in San Francisco Bay until recruiting in large numbers in Feb. 2005; population dynamics may reflect differential colonization of, or adult survival on, regionally distinct strains of the host algae *Vaucheria* spp. Southern *Vaucheria* strains may limit slug body size, selecting against planktotrophy in the southern species by limiting fecundity in the face of high planktonic mortality.

96 SHALLOW SURF RIDERS: SMALL-SCALE LARVAL DISTRIBUTION IN ESTUARINE WATERS

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Larval supply to settlement sites strongly affects the distribution of marine organisms, but it is unclear how physical properties of the water column influence larval abundance at small spatial scales. We measured the near-bottom concentration of larvae over shallow mudflats in Newport Bay and the Cabrillo Wetland, San Pedro. For 12 months, larvae were sampled 1–10 cm above the substratum over a 3 hr flood tide for 3 consecutive days per month per site. Larvae were sorted live, grouped by taxon and identified to genus or species by DNA sequencing. Day-to-day variance in larval abundance was unexpectedly high, and concentrations were often radically skewed between the 2 heights on a given day, but evenly or reverse-distributed the next day. Such changes in small-scale distribution were observed for all major taxa, although spionid and barnacle larvae were consistently more abundant at 5 cm. Overall abundances at Newport were 3× higher for veligers, 17× higher for spionids, and 31× higher for pediveligers than at Cabrillo, whereas barnacle nauplii were 5× more abundant at Cabrillo. Flow measurements were recorded near the bed using an Acoustic Doppler Velocimeter (ADV) during sampling, revealing complex oscillatory flows; hydrodynamics may cause near-bottom fluctuations in larval abundance.

97 RAPID ASSESSMENT OF TERRESTRIAL AND MARINE HABITATS USING TWO NOVEL METHODS FOR ESTIMATING THE DENSITIES AND DISTRIBUTIONS OF ORGANISMS

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Two novel plotless mathematical solutions for rapidly estimating the densities and distributions of organisms are proposed. The accuracy and precision of these estimations using these equations were compared to those obtained by methods commonly used in the field, including both line transect and nearest neighbor methods as well as stratified random quadrat sampling and belt transect sampling. The performances of both the novel and established methods were determined by estimating densities and distributions on simulations with varying sizes and dispersions of an organism. Field tests of the methods were then conducted in the chaparral habitat in Santa Clarita, CA as well as in the rocky intertidal zone at White's Point, CA. In both the simulation and field tests, the proposed methods often produced more precise and accurate estimates of densities, and to a lesser extent distributions, than the other methods. The novel equations were also more robust than established methods in terms of more accurate density estimations when using varying sample sizes and organism dimensions.

98 ON SOUTHERN CALIFORNIA ABYSSAL ECHINODERMS

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Echinocrepis rostrata Mironov, 1973 is an abyssal echinoid found in the northwest Pacific and in the eastern Pacific from Alaska to Mexico at depths of 3315 to 5020 meters. There are two distinct morphological types, one in the northwest Pacific and one in the northeast Pacific south to 34° N. Specimens of *E. rostrata* in the Scripps Institution of Oceanography Benthic Invertebrate Collection are of the morphological type found in the northeast Pacific. *Cystocrepis setigera* (A. Agassiz, 1898) is an abyssal echinoid found in the eastern Pacific from Alaska to Peru at depths of 2330 to 4100 meters. There is a collecting record for *C. setigera* in the central north Pacific at the Magellan Rise seamount (7° N 176° W; 3100 m). This is the only non-eastern Pacific record for this species and this may be due to the lack of sampling west of the eastern Pacific continental shelf. In the Peru trench *C. setigera* has a high level of ectosymbiosis; however, individuals of this species off the central California coast show that ectosymbionts are either extremely low in number or absent. *Pythonaster pacificus* Downey, 1979 is an abyssal asteroid described from a single specimen collected off southern California (31° 19.7′ N 119° 39.2′ W; 3600 to 3676 m). An additional specimen of this species is in the Scripps Institution of Oceanography Benthic Invertebrate Collection (32° 03′ N 120° 30′ W; 3777–3792 m). A live *P. pacificus* has been seen in camera sled imagery partially buried in mud (34° 42.11′ N 123° 11.185′ W; 4100 m).

99 THE DEEP SEA HOLOTHURIAN *SCOTOPLANES GLOBOSA* OFF SOUTHERN CALIFORNIA

K.D. Trego. Nautilus Oceanic Institute, La Jolla, CA 92037

Scotoplanes globosa Théel, 1879 is a cosmopolitan deep sea holothurian found at depths of 545 to 7710 meters. The aggregate behavior of this species is well documented as mobile grazing aggregations of *S. globosa* feed on kelp falls, detrital deposits, and whale falls. The aggregate behavior of this species is also well documented in the Santa Catalina Basin and San Diego Trough. These are bathyal basins where *S. globosa* is found to be common. *Scotoplanes globosa* was studied in the Santa Catalina Basin by submersible at 1300 meters and in the San Diego Trough by at 1243 meters. Large numbers of *S. globosa* taken in single trawls may indicate aggregate levels present at the trawl sites. The Scripps Institution of Oceanography Benthic Invertebrate Collection has large single trawl lots for *S. globosa* from the San Diego Trough, Tanner Basin, and East Cortez Basin at depths between 1200 to 1400 meters. There is also a large single trawl lot for San Nicholas Basin at 1738 meters. Tanner Basin, East Cortez Basin, and San Nicholas Basin may be additional bathyal basins where *S. globosa* may be found in feeding aggregations.

100 TOOLS FOR TRACKING THE FATE OF WASTEWATER-DERIVED CONTAMINANTS IN EFFLUENT-DOMINATED WATERS

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Municipal wastewater effluent contains low concentrations of a variety of chemical contaminants of concern to human health and aquatic ecosystems. Some of these compounds are difficult to measure with conventional analytical methods. To track the sources and fate of wastewater-derived contaminants in surface waters, we have developed a suite of tracers that can be used to assess dilution and transformation reactions that occur in the aquatic environment. For example, enantiomers of the human pharmaceutical propranolol can be used to differentiate between untreated sewage and wastewater effluent because the compound undergoes enantiomer-selective degradation in wastewater treatment plants. This tracer can be used to identify sites where leaking sewers or combined sewer overflows impact water quality. Total organic iodine can be used as a tracer for the fraction of a water sample that is derived from wastewater effluent because the main sources of organic iodine are the X-ray phase contrast media used in medical imaging. In a similar manner, wastewater-derived contaminants that are known to degrade by different mechanisms (i.e., reactive tracers) can be used to assess contributions of contaminants from combined sewer overflows and the transformation of contaminants by processes such as photochemical reactions and biotransformation. Application of these techniques should provide a better understanding of how wastewater-derived contaminants are attenuated in the aquatic environment and in engineered treatment systems.

101 CONTAMINANT FATE AND SOURCE TRACKING USING CHIRAL AND STABLE ISOTOPE ANALYSIS

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Toxic organic contaminants continue to pose ecological and human health risks in coastal urban systems, however, identifying their sources and tracking their fate in complex watersheds remains challenging. For constituents of legacy and currently registered biocides that are chiral (e.g. DDT, toxaphene, cypermethrin), enantioselective GC- and LC-MS allows for quantification of enantiomer abundances/ratios, proxies for determining the extent of biotransformation acting on these compounds. Another powerful diagnostic tool is compound specific isotopic analysis (CSIA) where, for example, stable isotopes of carbon associated with individual chromatographic peaks are quantified after combustion to CO_2. The underlying principle for applying CSIA is that stable isotope ratios (e.g. $\delta^{13}C$) shift when chemical bonds of the parent compound are broken, e.g. as a result of microbially-mediated enzymatic reactions. On the other hand, unchanging $\delta^{13}C$ values in a given watershed suggest little in situ transformation. These tools are being developed and applied in coastal environmental research to track and apportion contaminant sources, and to characterize the contaminant biotransformation potential of species, communities and ecosystems.

102 CHEMICAL METHODS FOR MEASURING BIOAVAILABILITY

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In multi-phase matrices, phase distribution determines the bioavailability and hence the ecotoxicological effects of a contaminant. For a hydrophobic pollutant, it is well recognized that its availability for bioaccumulation or toxicity is reduced due to association with colloidal particles and dissolved organic matter (DOM). The reduction in bioavailability is influenced by both the quantity and quality of the colloidal and DOM phases. As the fine colloids and DOM are essentially inseparable from the aqueous phase, quantifying bioavailable concentrations is a great challenge. This presentation will discuss several tested physical-chemical approaches for measuring bioavailability of hydrophobic organic contaminants, and their advantages and limitations. The second half of this talk will introduce solid-phase microextraction (SPME) and its unique applicability for detecting bioavailable concentrations. Studies show that SPME fibers mimic membranes or lipids of organisms, and chemical accumulation in the SPME fiber is parallel to bioaccumulation or toxic effects observed in test animals. SPME can therefore be used as a "biomimetic" surrogate to estimate contaminant bioavailability in sediment porewater, soil, runoff effluents, or "brown" surface water.

103 WATER QUALITY ON SWIMMING BEACHES: NEW DIRECTIONS FOR THE EUROPEAN UNION

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On 24 October 2002, the European Commission adopted a proposal for a revised Directive of the European Parliament and of the Council concerning the Quality of Bathing Water on swimming beaches in the European Union. This proposal is called COM 581 and is part of a sweeping 3rd wave of water directives, changing the face of environmental policy in Europe. Since the original directive was published there have been many changes to science, technology and the management of the environment. Within Europe since the early 1990s there has been a progressive move towards assessing water bodies holistically rather than just addressing human inputs and concerns. With new approaches, competent authorities such as water providers, environmental protection agencies and local authorities face new challenges to develop the systems that are prescribed in the new directive. Success in this is critical to best practice within coastal management and the associated social, economic and environmental aspects. The overall aim of my research is to develop methods and approaches to support the competent authorities involved, through a Bathing Water Management Framework (BWMF). Using an inter-disciplinary model, this paper shall explore the three areas of greatest change in bathing water policy. These are: legislation and management development, biomonitoring, and communication to the public. This approach will ultimately lead to the development of a framework to assist competent authorities in improving management of beaches as entire ecosystems that are safe for human use.

104 CONTAMINANT TRENDS IN THE SOUTHERN CALIFORNIA BIGHT: A MUSSEL WATCH UPDATE

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Since 1986, mussels from about 21 sites in the Southern California Bight have been analyzed for trace contaminants as part of NOAA's National Status and Trends Program. Recent data (through 2002 and 2003) show few significant changes to trends through 1998–1999 we reported in the 2002 SCAS conference. With one notable exception, concentrations of organochlorines (PCBs, DDTs and other pesticides) and butyltins (from antifouling paints) continued to decline through 2002/2003. Whereas concentrations of PCBs were below 200 ppb dw at most sites, those at two sites in San Diego harbor remained elevated above 1000 ppb dw. The highest concentrations of DDTs in 2002/2003 (753 ppb dw) occurred at San Pedro Fishing pier inside the LA/LB Harbor breakwater, with concentrations decreasing by 1–2 orders of magnitude upcoast and downcoast (e.g., 11.7 ppb dw at Point Loma). Nonetheless, since 1990 concentrations of DDT in mussels from all 21 stations declined an average of 53% (range 13 to 87%), giving a regional half-life of about 10 years. Chlordanes, heptachlors, and several other organochlorines compound classes remain measurable at low concentrations. Total polycyclic aromatic hydrocarbons (sum of over 40 PAHs) show continued elevated concentrations at several sites, with fingerprints suggesting dominance of pyrolytic sources. Trace metal concentrations have changed little over the past two decades, with the notable observation of higher cadmium concentrations at remote sites. Continued monitoring, coupled with comparison to chemical mass inputs from major sources (point, nonpoint) could reveal the effectiveness of pollution control efforts during the past two decades.

105 A COMPARISON OF TRACE METAL CONCENTRATIONS IN DEEP OFFSHORE AND NEARSHORE SEAWATER FROM SOUTHERN CALIFORNIA

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An important route for the uptake of trace metals into marine organisms is dissolved metals directly from their environment. Results for trace metals using extraction/chelation followed by ICPMS analysis will be compared between deep offshore seawater (800m) and nearshore harbor seawater. The concentration of several elements were significantly higher in the harbor water. The concentrations will also be compared to the several reference sources for seawater metals concentrations and the California Ocean Plan requirements. Finally, for the nearshore samples a comparison of the dissolved versus particulate metals concentrations will be presented indicating where the metals are partitioned.

106 HEAVY METAL ACCUMULATION IN SEA TURTLES FROM THE BAJA CALIFORNIA PENINSULA, MEXICO

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Heavy metals were assessed in four species of sea turtles from the Baja California Peninsula, Mexico, representing the first report of heavy metal concentrations in tissues of post-yearling sea turtles from the Eastern Pacific. Concentrations of Cd measured in C. mydas kidney (652.57 μg/g) were the highest ever reported for any sea turtle species. Cd accumulated preferentially in kidney and the range of kidney to liver Cd ratios in Baja California turtles were among the highest reported for sea turtles globally. Zn, Ni, and Mn concentrations were also significantly higher in kidney than other tissues, while Cu and Fe were greatest in liver, and all metals were lowest in muscle. With the exception of one value (69.9 μg/g in kidney of C. caretta), Pb was low in all tissues from Baja California. In comparisons across species, kidney of C. mydas had greater Zn and Ni concentrations as compared to other species, although there was no difference in liver metal levels among the species. Positive correlations were detected in the concentrations of Cd, Cu and Ni with the straight carapace length of C. caretta. Potential sources of high concentrations of metals in Baja California coastal ecosystems will be discussed and compared to the US State of California.

107 PROBING METAL-LIGAND INTERACTIONS USING STABLE ISOTOPICALLY LABELED PROTEINS AND DIRECTLY COUPLED HPLC-ICP-MS

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The transcriptional induction of metallothionein (MT) by reactive oxygen species (ROS) and elevated levels of metals such as Cd, Cu and Zn has been used to support the concept that this protein can be used as a sub-cellular biomarker for metal contaminant exposure and oxidative stress. Although not explicitly stated, the basic assumption in the use of the protein in this context is that the steady-state cellular concentrations of metallothionein qualitatively or quantitatively reflect the degree of contaminant exposure in a manner that the response can provide early warnings of deleterious sublethal effects. Conceptually, this paradigm is in accordance with the proposed protective function of MT in metal or ROS detoxification. However, more recent evidence indicates that this protein family may function primarily in metal homeostasis and the redox-mediated distribution of Zn in animal cells, implying that protein expression may be uncoupled from stressor exposure. The current work describes a novel ICP-MS procedure that has been used to directly probe the functionality of MT and the ability of the two major isoforms, MT-1 and MT-2, to exchange Zn and to selectively deliver Zn and Cd in a redox specific manner to intracellular protein targets, causing both enzyme activation and inactivation. With further refinement, the technique has the potential for studying the synergistic and antagonistic interactions of different metals with multiple donor and recipient proteins. It therefore offers a procedural framework for empirically testing the behaviour of more complicated scenarios of metal-ligand exchange, which is the basis for understanding the cellular toxicity of essential and non-essential metals *in vivo.*

108 STRATIFYING BAY AND ESTUARY HABITATS OF THE WEST COAST OF THE CONTIGUOUS USA: A STEP TOWARD REGIONAL INDICATORS OF BENTHIC COMMUNITY CONDITION

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We identified benthic assemblages occurring naturally in soft bottoms of bays and estuaries of the west coast of the contiguous US and evaluated the importance of geography and habitat in structuring them. Species abundance, habitat and contaminant data from 1318 samples collected by five regional and coast wide projects were adjusted for compatibility and combined. Because our objective was to define natural groupings of samples, potentially polluted sites were eliminated. Assemblages were then identified by hierarchical cluster analysis of species abundances in the 714 remaining samples. Latitude, salinity, grain size distribution and depth values were tested across dendrogram splits to assess whether the assemblages occupied different geographic regions or habitats. Overall, eight assemblages were identified, structured primarily by salinity, geography and sediment grain size. Geographically distinct high salinity assemblages were identified in southern California, Puget Sound and the west coast from central California to Washington State. In contrast, transitional salinity and freshwater assemblages were widely distributed along the coast. These assemblages may be viewed as alternate, habitat-dependent states of reference condition that can be used to identify impaired benthos. Most likely, regional indicators of benthic invertebrate community condition will differ from assemblage to assemblage.

109 INFESTATION OF PARASITIC COPEPODS AND THE POTENTIAL OF STRESS ON HOST FISHES

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While it is widely known that the southern California marine environment has been subjected to numerous inputs of pollution, little is known about the effects of pollution on infestation of parasites on marine fishes. Exposure to pollution may result in stress, which may potentially decrease the immune response in fishes and increase their susceptibility to diseases and parasites. A variety of marine organisms have been evaluated as potential biological indicators of various forms of pollution in the aquatic environment. However, due to the range of contaminants to which marine organisms are exposed, it is unclear which organisms and which anomalies are best used as indicators. In addition, it is unclear to what degree parasites cause stress to their host and what long term damage occurs to host physiological responses. Chronic stress can inhibit an organism's normal physiological response to the environment. Thus, fishes may be subjected to two major forms of environmental stress; parasites and poor water quality. The California scorpionfish, *Scorpaena guttata,* is common in southern California and is frequently infested with parasitic copepods. Intensity levels of parasitic gill copepods, *Naobranchia scorpaenae,* vary per host and can sometimes be as high as 100 copepods per gill cavity. Levels of the stress hormone cortisol and infestation levels of ectoparasites were compared from scorpionfish collected at various predetermined stations in southern California. Sampling occurred near the Orange County Sanitation District wastewater outfall. Preliminary results suggest an abnormal response in cortisol levels in groups of fish with high parasite prevalence.

110 DISRUPTION OF THE STRESS RESPONSE ENDOCRINE SYSTEM IN MARINE FISHES IN THE SOUTHERN CALIFORNIA BIGHT

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Connections between environmental contamination and impairment of endocrine mechanisms regulating key physiological systems in marine fishes are not understood, particularly in southern California. All vertebrates respond to environmental stressors via a highly integrated neuroendocrine response system which, in fish, is referred to as the hypothalamo-pituitary-interrenal (HPI) axis. Activation of the HPI axis results in synthesis and release of the steroid hormone, cortisol, into the blood circulation and, depending on the nature and severity of a stressor and the fish species tested, plasma cortisol concentrations may increase up to 200-fold over basal levels. In our studies in fish from the Bight, we have identified instances in which the HPI axis shows severely blunted responses, including after conditions of chronic stress in captive fish and in fish captured in the vicinity of wastewater treatment plant outfalls. This impairment of the stress response system may occur at one or more levels of the HPI axis, in addition to possible alterations in steroidogenic or metabolizing enzyme expression. Our studies, aimed at these questions, will be addressed.

111 GROWTH ENDOCRINE DISRUPTION IN SOUTHERN CALIFORNIA MARINE FLATFISH

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Our research to date indicates that important endocrine systems may be altered in marine flatfish of southern California. One of these systems, that which regulates somatic growth and a host of related anabolic functions, is the insulin-like growth factor (IGF) axis. Increased circulating levels of IGF-I and IGF-binding protein-3 (IGFBP-3) promote growth, while decreased IGF-I levels combined with increased levels of IGFBP-1 are characteristic of growth inhibition. IGFBP-1 has a high IGF-I-binding affinity and blocks IGF-I activation of target cell receptors, and it is up-regulated by the stress hormone, cortisol. IGF-I expression and plasma levels, on the other hand, may be inhibited by cortisol, estrogens or other compounds. In flatfish caught in certain locales in the southern California bight, IGF axis alterations occur in individuals exhibiting impaired stress responsiveness (neuroendocrine HPI axis), while putative relationships between the IGF axis and plasma estradiol are less clear.

112 BIOACCUMULATION OF CONTAMINANTS IN RECREATIONAL AND FORAGE FISHES IN NEWPORT BAY, CALIFORNIA IN 2000–2002

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Newport Bay is an important southern California estuary that is both a developed marina in its lower bay and an ecological reserve in the upper bay. Recreational anglers catch fish for consumption, particularly in the lower bay, and threatened bird species consume small forage fish in the upper bay. The objectives of this study are to 1) provide recent data on contaminant levels in Newport Bay fishes, 2) identify species with concentrations posing potential health concern to humans or wildlife, and 3) identify species or ecological groups of fishes with high concentrations. Target contaminants included semivolatile organic compounds (DDTs, other pesticides, and PCBs) and trace metals (arsenic, mercury, selenium, and cadmium). Fourteen recreational and nine forage fish species were analyzed for these contaminants. Many fishes of Newport Bay have tissue contaminant levels above screening values (SVs) for human or wildlife fish consumption. DDT was the most widespread contaminant of concern in fish tissue, followed by PCBs. Five recreational fish species were above the human health SV for DDT and three for PCBs. All nine forage fish species were above the SV for wildlife health for DDT but only three were above that for PCBs. Three forage fish species had selenium levels above the wildlife SV. Although DDT was widespread in all species, other contaminants were associated with ecological types of fish. Although DDT, PCB, and selenium levels in some species are still of concern, concentrations of these contaminants have declined substantially during the past 25 years.

113 OXIDATION OF SELENOMETHIONINE BY FLAVIN-CONTAINING MONOOXYGENASES (FMOS)

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Selenium biotransformation into organoselenium forms by primary producers and subsequent accumulation by higher food chain organisms such as fish are critical for mechanistically understanding the adverse effects of selenium in aquatic organisms. Although previous laboratory and field studies have both demonstrated a good correlation between adverse effects and total selenium in fish tissue, direct confirmation of the most toxicologically important forms of organoselenium is lacking, with nearly all measurement being total selenium. To illustrate this, we hypothesize that following accumulation by fish organoselenides are oxidized to selenoxides by flavin-containing monooxygenase (FMO) upon the consumption of NADPH and oxygen. The generated selenoxide can be reduced to organoselenide by consuming the antioxidant glutathione. With the continuous redox cycling between organoselenide and selenoxide we hypothesize, glutathione will be depleted eventually resulting in cellular toxicity. Therefore, in this study, an *in vitro* substrate dependent NADPH oxidation assay was performed to test the first step of the hypothesis, the oxidation of organoselenium by FMO. A series concentration of the organoselenide selenomethionine (0.05 2.0 mM) was incubated with 0.2 mM NADPH and 100 μg microsomal FMO1 or FMO3 proteins in 50 mM KPO4 buffer (pH 8.4) at 37 C. The absorbance of NADPH (340 nm) of the reaction mixture was measured over 30 min at 5 min intervals, and a NADPH extinction coefficient of 6220 M-1 cm-1 was used in calculating catalytic constants. The results show that both FMO1 and FMO3 demonstrate catalytic activity for selenomethionine, with FMO3 having a lower Km than FMO1 (i.e, 172 μM and 617 μM, respectively), indicating that FMO3 is more reactive in catalyzing the oxidation of selenomethionine to the oxide.

114 ENANTIOSELECTIVITY IN PYRETHROID DEGRADATION IN SOIL

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Synthetic pyrethroids contain two or three chiral centers, making them a family of pesticides with the highest number of enantiomers. Our recent study showed significant differences in aquatic toxicity between the stereoisomers of the same compound. To better understand the ecotoxicological effect and fate of synthetic pyrethroids, chirality in biodegradation of pyrethroid compounds should be also considered. In this study, enantiomers of *cis*-bifenthrin were isolated on chiral HPLC and the enantiopure isomers were examined individually for degradation rate in two soils under the same conditions. Degradation of each enantiomer was studied at 20°C under both aerobic and anaerobic conditions. The study results show that R-*cis*-bifenthrin degraded faster than S-*cis*-bifenthrin under aerobic conditions in both soils. However, under anaerobic condition, S-*cis*-bifenthrin was found to have a faster degradation rate. Isomer conversion did not occur during degradation in soil. As only biological interactions can be chiral selective, the enantioselectivity observed in degradation of *cis*-bifenthrin should be a result of different microbial communities under different test conditions.

115 ENANTIOMERIC SULFOXIDATION OF THE ORGANOPHOSPHATE PESTICIDE FENTHION IN FISH

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The objective of this study is to examine the enantioselective sulfoxidation of fenthion, in liver microsomes of various fish species (rainbow trout, hybrid striped bass, tilapia). Microsomes from striped bass, trout, and tilapia primarily formed (-) sulfoxides in approximately 65% enantiomeric excess. Enzyme inhibitors lubrol (cytochrome P450) and methimazole (Flavin Monooxygenases) were used to determine sulfoxide relative contributions from each enzyme system. In striped bass microsomes, P450 was responsible for 74% of sulfoxide formation. Co-incubation with methimazole or lubrol in trout liver microsomes enhanced sulfoxide formation. Salt water treatments which typically induce FMOs, did not significantly alter enantioselectivity or rates of fenthion sulfoxidation, even though toxicity tests indicated that saline environments enhanced the toxicity of fenthion in trout.

These results indicated either the formation of additional metabolites of fenthion or the contribution of additional oxygenases to S-oxidation.

116 LINKING BIOMARKER RESPONSES AND PHYSIOLOGICAL STRESS TO GROWTH IMPAIRMENT OF CADMIUM-EXPOSED LARVAL TOPSMELT

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An integrated approach was used to determine if key biochemical, cellular, and physiological responses were related to growth impairment of cadmium (Cd)-exposed larval topsmelt (*Atherinops affinis*). Food intake, oxygen consumption rates, apoptotic DNA fragmentation (TUNEL assay), and metallothionein (MT)-like protein levels, were separately measured in relation to growth of topsmelt aqueously exposed to sublethal Cd for 14 days. Cadmium accumulation and abundant metal concentrations in topsmelt also were evaluated. Final mean weight and length of Cd-exposed topsmelt were reduced relative to those of control fish. Food intake was weakly correlated with weight of Cd-exposed topsmelt. Oxygen consumption rates were positively correlated with Cd concentration and inversely correlated with weight of topsmelt. Apoptotic DNA fragmentation was elevated in the gill of fish exposed to 50 ppb Cd, and in the gut, gill, and liver of fish exposed to 100 ppb Cd. Metallothionein-like protein levels were significantly elevated in fish exposed to 100 ppb Cd. Oxygen consumption rates may have increased as a compensatory response to Cd exposure; however, the energy produced was likely allocated to an increased metabolic demand due to apoptosis, MT synthesis, and ion regulation changes. This diversion of energy expenditures could contribute to growth impairment of Cd-exposed fish. The integration of biomarker responses across levels of biological organization will advance our understanding of mechanisms through which fitness becomes impaired.

117 ARTHROGRYPOSIS FOLLOWING ACRYLAMIDE EXPOSURE

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Arthrogryposis multiplex congenita (AMC) is a term that is used to describe the presence of multiple joint contractures at birth. AMC is a syndrome, involving many fetal and neonatal disorders of the neuromuscular systems. The mother of the subject worked in a biomedical laboratory using polyacrylamide gels in electrophoretic studies of nucleic acids. Working without respiratory protection throughout her entire pregnancy, she experienced her greatest exposure to the monomer, acrylamide. Exposure to acryiamide throughout the mother's pregnancy is judged to be the etiology of the subject's arthrogryposis. This is the first occupational prenatal exposure to the monomer acrylamide to be implicated as a possible etiologic agent in a case of arthrogryposis.

118 EXPRESSION AND CHARACTERIZATION OF CHANNEL CATFISH CYP 2X1

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Previous studies of channel catfish identified a novel cDNA encoding the cytocrome P450 isoform, CYP2X1. To better characterize CYP2X1, the protein was expressed in Sf9 cells and examined for catalytic ability. A pFastBac ™ 1 donor plasmid, containing the CYP2X1 reading frame, was transferred to the bacmid DNA (Baculovirus genome) at the Tn7 site-specific transposition in DH10Bac competent cells. Isolated microsomes from Sf9 cells demonstrated a maximum CO reduced spectrum at 450nm, and exhibited a band at approximately 57 kD on SDS-PAGE. CYP 2X1 catalyzed Benzphetamine and Aminopyrine demethylase activity at 0.1888 nmol/min and 0.043 nmol/min respectively. However, enzymatic activity was not observed following incubation with p-Nitrophenol, Fenthion, Benzylresorufin or Pentoxyresorufin. These results indicate CYP2X1 displays activities consistent with other piscine CYP2 isoforms.

119 IDENTIFYING ALUM AS A TOXICANT IN WHOLE EFFLUENT TOXICITY TESTS

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Alum (aluminum sulfate) is a commonly used flocculant in the wastewater treatment process. Dosing levels of alum are made at the discretion of POTW's based upon several water quality factors. Chronic effects were observed in the cladoceran *Ceriodaphnia dubia* and the green algae *Selenastrum capricornutum* during routine testing of tertiary treated effluent from a municipal wastewater treatment plant. Several consecutive toxic samples prompted a Toxicity Reduction Evaluation (TRE) at the plant, whereby Phase I Toxicity Identification Evaluation (TIE) tests indicated higher sensitivity in *Selenastrum* to the effluent than *Ceriodaphnia,* with no effects observed in *Pimephales promelas.* Filtration reduced the toxicity of the effluent in Phase I TIE tests using *Ceriodaphnia,* and subsequent Phase I TIE fingerprint tests of several compounds showed alum to produce patterns consistent to the effluent in terms of dose response, species sensitivity and toxicity reduction by filtration. The dose response levels appeared consistent with the average daily dose of alum at the treatment plant, and additional tests in which laboratory control water was diluted to match the hardness of the effluent showed even lower dose response levels in *Selenastrum.* The observed physical effects of alum on the green algae included clumping of multiple cells and decreased cell counts. This provides a possible mechanism for the chronic effects in *Ceriodaphnia,* which uses *Selenastrum* as a food source, and may explain the insensitivity of *Pimephales* to the effluent, which uses a larger, multicellular food source. Reduced alum dosing at the plant in response to this study appeared to confirm these findings, as subsequent effluent tests showed no chronic effects in either *Ceriodaphnia* or *Selenastrum.*

120 DEVELOPMENT OF A MACROINVERTEBRATE IBI FOR SOUTHERN COASTAL CALIFORNIA AND USE OF PROBABILISTIC SAMPLING FOR REGIONAL STREAM CONDITION ASSESSMENTS

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We developed a macroinvertebrate index of biological integrity (IBI) for the arid and populous southern California coastal region. Potential reference sites were screened from a pool of 238 sites with quantitative GIS landscape analysis and with reach-scale physical habitat assessments. We evaluated correlations among a suite of potential stressor gradients to identify a set of 10 independent reach, local and watershed scale stressors. To select component metrics for the IBI, we screened 61 candidate metrics for suitability with regard to three criteria: sufficient range for scoring, responsiveness to the 10 stressor gradients and minimal redundancy with other responsive metrics. Seven final metrics (Percent Collector-Gatherer + Filterers, Percent Non-insect Taxa, Percent Tolerant Taxa, Coleoptera Richness, Predator Richness, Percent Intolerant Individuals and EPT Richness) were scored and assembled into a composite IBI which was then divided into five equal condition categories. Three metrics had lower scores in chaparral reference sites than in mountain reference sites and were scored on separate scales in the IBI. A separate repeatability study and application of the IBI to an independent validation dataset confirmed that IBI scoring is highly consistent. Data from probabilistically selected sites allowed us to develop a defensible condition assessment for streams in the region.

121 ALGAE-NUTRIENT RELATIONSHIPS AND TMDL DEVELOPMENT IN MALIBU CREEK, CALIFORNIA

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Periphyton cover in Malibu Creek was sampled in spring and fall. Multiple regressions of periphyton cover with nutrients, canopy cover and substrate size indicated nutrient concentrations were most often related to periphyton cover, and canopy was the next most important factor after nutrients. Nutrient concentrations in the water and percent cover of periphyton were lower at reference sites than at impacted sites. Relationships between periphyton cover and nitrate concentration, phosphate concentration and canopy cover varied seasonally. Nitrate concentration had the strongest relationship with macroalgal cover in the spring and phosphate concentration had the strongest relationship with macroalgal cover in the fall. Phosphate was consistently positively related to microalgal cover regardless of season. Nitrate was sometimes positively and sometimes negatively related to microalgal cover.

122 FRESHWATER STREAM INVERTEBRATES: RESPONSE TO PHYSICAL HABITAT ALTERATION AND WATER QUALITY IMPAIRMENT IN SOUTHERN CALIFORNIA

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Biomonitoring of the benthic macroinvertebrate communities has become a widely used tool to monitor the effects of non-point source pollution in urban runoff. In coastal Southern California, physical alteration of natural drainages in the form of impervious surfaces and lined flood control channels has compounded the issues of biomonitoring, as the degraded physical habitats are not considered ideal for biological uses. Interpretation of biomonitoring results in drainages with physically altered habitats becomes difficult when water quality and physical habitat quality must be weighed to determine which has a greater effect on use attainability by the macroinvertebrate community. Three regional stream bioassessment monitoring programs were conducted in Los Angeles, Orange, and San Diego Counties in October of 2003 as required for municipal NPDES permit compliance. A total of 54 monitoring sites from 22 different watersheds were assessed using the California Stream Bioassessment Procedure (Harrington 1999). Data analysis incorporated a recently developed Southern California Index of Biotic Integrity (Ode et al In Press) to rate quality of benthic macroinvertebrate communities. Physical habitat quality was quantified using EPA Rapid Assessment protocols. Results of our studies indicate that the biological integrity in urban affected watersheds in Southern California has been substantially degraded. We have also determined that while physical habitat may limit macroinvertebrate colonization to some degree, the lowest quality communities did not occur in the most altered or poorest quality physical habitats. Correlating the quality of the physical habitats of streams and the quality of the benthic communities they support indicates that there is little relationship in the presence of urban runoff.

123 THE APPLICATION OF STREAM BIOASSESSMENTS IN POINT AND NON-POINT SOURCE REGULATORY PROGRAMS

Scott Johnson

No abstract available.

124 USE OF *IN SITU* HATCHBOX STUDIES TO EVALUATE WATER QUALITY EFFECTS

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Laboratory toxicity tests have been criticized on the basis that their results may not reflect site-specific conditions. Conversely, interpreting the results of bioassessment studies may be problematic due to the inability to control for the movements of organisms in the receiving environment, as well as difficulties distinguishing between water quality and habitat effects. Thus, the use of *in situ* studies may provide an opportunity to quantitatively evaluate the potential effects of a discharge under the conditions found in the actual receiving environment. This presentation describes the approach used at the Myra Falls mine to evaluate the potential for discharge effects in the receiving environment. Eyed trout embryos were placed in hatchboxes at different locations to identify any potential for toxicity in Myra Creek. The reference site was located upstream of the discharge, and potential impact sites were located downstream of the discharge. Hatchboxes were also placed at selected locations to identify possible inputs of contaminated subsurface flows. Both lethal and sub-lethal endpoints were evaluated, including survival, hatching success, and growth.

125 THE EFFECTS OF SEQUENCING: MEMORY ITEMS VS. PERCEPTUAL LEARNING

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This study examined adaptive learning as it pertains to learning of memory items and perceptual learning. It studied how the order in which items are presented can be manipulated to make both types of learning more efficient. Fifty-four subjects completed a learning module that would teach thirteen multiplication problems and thirty-nine subjects completed a learning module that would teach them to discriminate between ten categories of beetles. Subjects were randomly assigned to one of three conditions with different sequencing. One condition applied known laws of learning and memory of memory items to an adaptive learning algorithm that used speed and accuracy to determine which item to present. The other two conditions used random presentation. The results suggest that the adaptive learning algorithm allows for better retention than random presentation where the items no longer appear after they have been learned. Although retention is slightly better for random presentation where the items continue to appear after they have been learned over the sequencing algorithm, this requires far more trials than sequencing, making sequencing more efficient

126 CREB-MUTANT PERFORMANCE IN A NOVEL LEARNING TASK

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The cAMP responsive element binding protein (CREB) is a nuclear protein that helps in transcription of brain-derived neurotrophic factor (BDNF). Through a series of intracellular signaling events CREB activates transcription of genes with cAMP responsive elements in their promoter regions. BDNF is a neurotrophic factor transcribed within brain cells that has been shown to play a vital role in learning and neuronal survival. CREB impairment would therefore inhibit memory and recognition in mutant mice. In this experiment the Y-Maze was used to test the extent of the effects of novelty versus experience on performance in the Y-Maze and its effect on BDNF levels in mice. Results acquired so far are somewhat significant. CREB mutants were injected with 4-hydroxy tamoxifen to activate the CREB repressor. Although in some cases mutants performed just as well controls, in most cases control mice performed noticeably better than mutants.

127 OPERATIONAL EFFECTS OF ALTERED ABIOTIC FACTORS ON NITRIFYING BACTERIA: YEAR 2

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A way to easily determine the feasibility of any method of preserving water quality in a specific water body is critical for the large-scale implementation of the method. Artificial addition of nitrifying bacteria to a water body can efficiently lower concentrations of ammonia, a highly toxic nutrient. A set of abiotic factors with respect to temperature, pH, salinity, and dissolved oxygen under which the bacteria can be expected to operate optimally would be instrumental in helping naturalists considering adding nitrifying bacteria to a natural water body make the decision.

The experiment was done by changing abiotic factors in tanks containing *Nitrobacter* and *Nitrosomonas* and water collected from Salinas de San Pedro, a salt marsh. The success of the bacteria was determined by testing concentrations of ammonia and nitrates. It was hypothesized that only salinity will have an effect on the bacteria.

The results showed that this was incorrect. The two genera of bacteria in the Biozyme favored different conditions of abiotic factors. Overall, the optimum water body for the nitrifying bacteria to operate in would have a temperature of about 30°C, a pH between 8.0 and 8.3, a salinity between 22 and 27 ppt, and a dissolved oxygen content between 5 and 9 mg/L. It should be noted, however, that in almost all cases, the bacteria operated as it should under unfavorable conditions, although its processes were somewhat delayed.

128 STRAIN RELATEDNESS OF *CANDIDA* IN HUMANS: A URINARY PATHOGEN OR COLONIZER? (PHASE 2)

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Candida species are commonly found the urine of hospitalized patients. Over 50,000 persons have this condition annually in the United States. This significance of this condition, candiduria, remains controversial. There is evidence that candiduria may represent a potentially serious and deadly bloodstream infection, or, alternately, merely represent urinary tract colonization. To provide important insights into the meaning of this condition, we examined strain relatedness of Candida strains from

over 300 patients causing infections among hospitalized patients of Harbor-UCLA Medical Center last year.

METHODS: We longitudinally examined 300 hospitalized patients with candiduria from Cedars Sinai Medical Center. Among those with >1 *Candida* strain isolated from the urine, we compared strain relatedness using usual clinical microbiological techniques and DNA fingerprinting. We hypothesized that *Candida* species would vary over time, suggesting that candiduria may represent host susceptibility to this condition rather than a persistent state.

RESULTS: Among the 300 patients, 89 had >1 analyzable candida strain. Mean number of cultures per patient was 2.787. Of these follow-up cultures (cultures done after the initial culture positive for candida), 54 were negative for *Candida,* 47 demonstrated a different *Candida* species or strain and 147 demonstrated the same *Candida* species and strain. Four patients went on to have bloodstream infections.

CONCLUSIONS: *Candida* in the urine tended to wax and wane with time, and occasionally are supplanted with other *Candida* strains. This demonstrates that candiduria commonly resolves and recurs, occasionally with a new species. This suggests that candiduria, rather than persistent, phenomenon and that the natural history of this process appears relatively benign in most cases.

129 MAINTAINING CORRECT BALANCE: SPATIAL CODING AND ITS DEPENDENCE ON NATURAL STIMULI

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The vestibular system in the inner ear decodes motion and acceleration. The utricle's otoconia deflect hair-like protrusions in ascending order, called the morphological polarization vector. MPVs are essential for spatial coding. The project examined what effect natural stimuli have upon MPV maintenance. Otoconia deficient *HET/HET* and otoconia producing HET /+ mice utricles were used. Thus, otoconia was the sole variable. The tissues were prepared with phaloidin fluorescence and were imaged with a confocal microscope. The angle was calculated using the kinocilium center and hair cell center. In data quantification, three similar utricle areas yielded a HET/+ to HET/HET average angle of 93.3° to 105.5°, 114° to 137.5°, and 91° to 100° respectively. The compared MPV angles showed similarity, which suggests that sensory coding is non-stimuli dependent. This experiment deductively narrowed the factors contributing to MPV maintenance, so that non-stimuli factors can be explored.

130 EFFECTS OF ATMOSPHERIC CARBON DIOXIDE ON THE NITROGEN FIXATION CAPABILITIES OF *TRICHODESMIUM*

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As a consequence of the rising levels of anthropogenic carbon dioxide in the atmosphere, the world ecosystems are undergoing unforeseen changes. The nitrogen cycle constitutes as one of the most important processes within the biological world, with nitrogen being one of the twenty-five necessary elements for life. Therefore, it is essential to understand of future marine ecosystems in regards to organic nitrogen influx. Here, the effects of increased atmospheric carbon dioxide on the nitrogen production capabilities of *Trichodesmium,* a marine cyanobacterium responsible for the majority of the nitrogen supply in its ecosystems, are measured. By taking advantage of the inverse relationship between pH and CO_2 absorption, *Trichodesmium* cultures were designed to grow in CO_2 conditions of the pre-industrial era, the current era, and predicted levels for the years 2060, 2180, and 2250. Per trichome, nitrogen fixation rates were found to sharply decrease by 2060 and level out for the future. Rates, accordingly to the results found, are the highest within the range of time studied. However, rates per mL were found to be in direct opposition, with rates increasing linearly from 2060 onward. Therefore, an increase in organic marine nitrogen influx can be expected to occur in the future if anthropogenic CO_2 continue to rise unabated. The consequences of this augmented nitrogen supply are unknown. The results from this particular research represent only one piece of the huge puzzle that constitutes the question of the effects of anthropogenic carbon dioxide on marine nitrogen cycles.

131 USING THE INHIBITORY EFFECTS OF ATP ANALOGS TO REGULATE MRNA PROCESSING: YEAR II

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A key element in gene expression, post-transcriptional processing proves to be essential for the vitality of a cell. Processing includes cleavage of the pre-mRNA and the addition of the poly(A)tail, which stabilizes the mRNA for transport outside of the nucleus in order to be translated into a protein. Defects in processing regulation are involved in diseases such as HIV/AIDS, thalassemias (a blood disorder), and can even play a role in tumor cell viability.

Recently, an *in vitro* coupled processing system that mimics processing *in vivo* has been created in our lab. During the development of this system, it was suspected that Cordycepin triphosphate (3'dATP), an ATP analog, inhibited cleavage and polyadenylation of RNA. This inhibitory effect implied that ATP might play an important role in mRNA processing.

To assess the role of ATP in mRNA processing, ATP analogs 3'dATP and Ara-ATP were introduced to coupled and uncoupled processing systems in pulse-chase assays. It was found that inhibition of processing was specific to ATP analogs. 3'dATP inhibited processing up to 25μM and Ara-ATP decreased processing efficiency by 43.5%. Data suggest that these ATP analogs interact at an allosteric site, thereby inducing a nonfunctional conformation, preventing processing. ATP interacts with proteins on the processing apparatus thereby regulating processing.

ATP-dependent regulation of cleavage and polyadenylation supports the new idea that the processing reactions are intertwined to efficiently express genes. In addition, harnessing this inhibitory effect from ATP analogs can be used to regulate over-expressed genes that cause diseases.

132 STUDY OF THE EFFECTS OF *NEURAL LAZARILLO* OVEREXPRESSION IN TRANSGENIC *DROSOPHILA MELANOGASTER*

Derek Tam. Alhambra High School. Mentor: Julien Muffat (laboratory of Pr. Seymour Benzer)

This project is aimed at discovering the effects of the overexpression of *Neural lazarillo (*NLaz) in *Drosophila.* Overexpression results in additional proteins of a certain gene being present in the organism. Previous research with a close homolog, *Glial lazarillo,* have led us to hypothesize that overexpression will increase lifespan and resistance to environmental stress. The human homolog of the two genes is Apolipoprotein D (ApoD). Its function is unknown, but it is upregulated in brain pathologies. We want to determine whether Nlaz can help slow aging in fruit flies or prevent neurodegenerative diseases, and gain a better understanding of ApoD in humans. I began by acquiring samples of Nlaz cDNA in plasmids, or bacterial vectors. Then the plasmids were transfected by electroporation into E.coli and several colonies were cultivated, replicating the vectors, which were then extracted by Miniprep. A restriction digest was conducted to cut out Nlaz. The Nlaz cDNA fragment was separated from the plasmid DNA by electrophoresis and will be cloned into the plasmid pUAST, which allows conditional expression in *Drosophila.* Once the final plasmid is constructed, it will be injected into *Drosophila* embryos. After careful selection we will obtain flies carrying the pUAST-NLaz transgene in their genome. These will be crossed to drivers to trigger the expression of NLaz with spatio-temporal control. I will test the progeny for increased lifespan and resistance to stresses (e.g. heat, hyperoxia). Results from this project will help us understand the role of ApoD in human aging and neurodegeneration.

133 3D MODEL OF ALGORITHM PERFORMANCE ON THE 3-SATISFIABILITY PROBLEM

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The Satisfiability problem consists of variables with two solutions: True or False and clauses comprising of variables connected through OR operators. In some instances, NOT operators are situated at the front of variables, negating variables. All clauses are further linked to one another using AND operators.

Using two algorithms, a model is created to analyze the performance. The two algorithms are the simulated annealing algorithm and a variant of the simulated annealing algorithm. These two algorithms were chosen because of its extremely high performance compared to the hillclimbing and genetic algorithm.

Due to the diversity of satisfiability problem, the experimentation was tested with a ratio of approximately 4.25:1. This creates a equal divide in solvable and unsolvable problems. The experiment was tested on three problems consisting of four variables and ten clauses. It is then modeled to analyze its performance on a small scale in order to incorporate it into larger scale problems.

The satisfiability problem is significant in many ways because of the NP-complete nature of the problem. By generalizing an efficient way to solving this problem, it can be applied to problems that have the same NP-complete property.

134 PROSTATE CANCER PREVENTION BY POLYPHENOLIC COMPOUNDS IN GREEN TEA

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Cancer is known to be one of the leading causes of death, and of those deaths, 40,000 cases are attributed to prostate cancer. In this study of chemoprevention for cancer, RWPE-1 prostate epithelial cells were used in conjunction with epigallocatechin gallate (EGCG), which is a major polyphenolic compound of green tea. Very recent studies have shown that green tea might possess factors, especially certain polyphenolic compounds, that would further the research for chemoprevention. In this particular experiment, EGCG is speculated to be able to inhibit protein kinase C (PKC), which is a receptor for tumor promotion. The RWPE-1 precancer cells were infected by EGCG and grown in soft agar. The cells then underwent several scintillation counter exams. Each test was aimed to find distinct data and results that proved EGCG could indeed inhibit PKC. The correlation between the concentration of EGCG used and the number of active cells and colonies supports this experiment's hypothesis and further confirms recent queries about the possibility of using green tea for future chemoprevention.

135 IMPORTANCE OF DROSOPHILA EIF4E-BINDING PROTEINS IN LIFESPAN REGULATION

Tony Au Lu. Alhambra High School. Mentor: Brian M. Zid; Teacher: Mr. Duane Nichols

Aging is unclear to scientists worldwide and yet people continue to be interested in ways to live longer; in Drosophila, when insulin levels fall, due to either genetic interventions or lack of nutrients a lifespan extension is seen. My previous research suggests that longer lifespan correlates with activation of the dFoxo gene, which is regulated by insulin levels, and reduced amounts of nutrients. This project therefore tests whether or not 4E-BP, which is downstream of the dFoxo pathway, is responsible for the increase in lifespan. Thus, it is hypothesized that if there is a lack of nutrition and if 4E-BP is upregulated, then 4E-BP will stimulate an increase in lifespan. In this study, Drosophila lifespan was studied with respect to various overexpressions of 4E-BP that differ in their composition of Gal4—PO163, or 109—drivers, which are Drosophila lines that express the yeast transcriptional activator Gal4 in a tissue specific manner. In addition, the Drosophila were fed protein in the form of yeast ranging from 0–4% yeast concentrations. I saw complex interactions between the levels of 4E-BP and the nutritional content of the food for the phenotype of lifespan. The results show overexpressed 4E-BP on low yeast has a 50% increase in lifespan while 4E-BP on high yeast, a 15% decrease in lifespan. Because the Drosophila genome shares 77% of their genes with the human genome, these findings may be applied to increasing human lifespan and allow us to study human mortality.

136 MOTHER'S CHARACTRISTICS AND HER CHILD FEEDING HABITS

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Obesity is one of the fastest growing public health problems in America. It has been established that weight problems in childhood lead to significant health problems later in life. Parents are the strongest and most direct influence on their children's eating habits, and eating habits that are established in childhood often persist through adulthood. By surveying mothers of diverse ethnic and socioeconomic backgrounds, correlations can be found that indicate which characteristics possessed by the mother influence her child feeding habits.

Several such variables have been studied by the use of surveys. The socioeconomic status of the mother, her depression, body dissatisfaction and acculturation all affect her feeding habits and thus her child's eating habits. Her influence is determined by considering her restriction of her child's eating, the pressure she places on her child to eat, her perceived feeding responsibility, her concern about her child's weight and how closely she monitors her child's eating. The study found that there is a positive correlation between the socioeconomic status of the mother and the pressure she puts on her child to eat. There were also negative correlations found between her acculturation to American society and her perceived child feeding responsibility and, again, the pressure she puts on her child to eat. These findings are important to discovering which mothers are more likely to misguide their children's eating habits and how mothers can be educated in helping their children make intelligent eating decisions for the rest of their lives.

137 ROLES OF AUXOTROPHIC MARKERS IN *CANDIDA ALBICANS* VIRULENCE

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Candida albicans is the most common human fungal pathogen that causes mucosal and disseminated infections. This dimorphic fungus, which exists as oval, single yeast cells but forms hyphae under favorable conditions, is the most common cause of yeast infections. The virulence factors, which determine the ability of *C. albicans* to cause damage to its host cells, will serve as promising targets for therapies against *Candida* infections. Therefore, we examined the nutrient auxotrophy as a potential modifier of virulence in *C. albicans.*

In order to determine the effects of auxotrophy for uracil, arginine, and histidine on virulence traits of *C. albicans,* BWP17 ($Ura^-Arg^-His^-$) strain was used as a parental strain to construct $Ura^+Arg^-His^-$ strains, $Ura^+Arg^+His^-$ strains, and $Ura^+Arg^+His^+$ prototrophic strains. To examine the ability of each newly created strain to express the virulence related traits, growth test on different selection media, hyphal formation, and endothelial cell damage assay were performed.

$Ura^+Arg^-His^-$, $Ura^+Arg^+His^-$, and prototrophic strains formed hyphae while BWP17 could not. The abilities of the newly constructed strains, which all are prototrophy for uracil, to cause damage to endothelial cells were significantly higher than that of BWP17. Therefore, prototrophy for uracil is essential for the full virulence traits of *C. albicans.* On the other hand, auxotrophy for arginine and histidine does not affect the virulence traits. In conclusion, inhibiting the production of uracil may be used to develop therapeutic agents that specifically target *Candida* infections.

138 PREDICTING MATERIAL FAILURE: CORRELATION BETWEEN DEFORMATION LUMINESCENCE AND HYSTERESIS

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Prediction of material failure would advance solid-state physics and revolutionize modern engineering. Scientists and commercial systems, currently, are unable to measure the impact of stress and, most importantly, to predict system failure. The objective of this study is to discover the molecular changes of materials under stress by analyzing the characteristics of deformation luminescence (DL). Such discovery leads towards the ultimate goal of predicting material failure.

Mechanoluminescent irradiated Lithium Fluoride (LiF) crystals were utilized in various experiments to investigate deformation luminescence as the material undergoes hysteresis, specifically the variables of stress, strain, load speed, and time duration. An Instron testing system was used to compress LiF at various loads, speeds, and cycles. Photomultipliers were used to capture photon emission data. Data was collected both manually and with an oscilloscope computer data acquisition system. Mathematical models were derived.

As LiF was stressed beyond its elastic limit, light was found to increase drastically in various mathematical functions against stress, strain, and time duration, signaling hysteresis. DL increases logarithmically to load speed. Accumulative total of photon emissions was found to be an accurate assessment of material health. DL was also found to be effective in detecting the presence of internal cracks and denoting the phenomena of fracture.

DL was found to be a superior indicator of hysteresis, the precursor to failure. The discoveries made in this study form the basis of a reliable failure prediction system. The findings will ultimately improve the safety and efficiency of vehicles, machines, and structures we use today.

139 CHANGES IN DENSITIES OF FECAL INDICATOR BACTERIA (FIB) OVER DIFFERING TIDAL FLOWS IN THE BALLONA WETLANDS, LOS ANGELES

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There are two main objectives of this experiment: 1) to create a mathematical model showing the relationship between turbidity, dissolved oxygen, pH, salinity, time from high tide, and levels of indicator bacteria for fecal contamination, and 2) to see if fecal indicator bacteria (FIB) densities differ with tidal flows from flood to ebb.

In the field samples were tested at a single location every half hour during 12-hour periods on 3 occasions for temperature, dissolved oxygen, and pH levels using the YSI 600R Sonde Electronic Probe. In the laboratory, turbidity was measured using a HACH 2100N turbidity meter, and densities of FIB (total coliforms, *E. coli,* enterococci) were determined using IDEXX Quantitray 2000 test kits and reagents based on enzyme substrate methods. A mathematical model was created showing the relationship between dissolved oxygen, turbidity, pH, salinity, time from high tide, and bacterial growth.

Results indicated that bacterial levels were higher with decreased dissolved oxygen, decreased salinity, and increased turbidity in a neutral pH. As bacterial levels rose, the dissolved oxygen and salinity reserves were depleted. Turbidity levels appear to increase as sediments are drawn off of the banks of the water column and resuspended from the bed of the creek. FIB appear to attach to the sediment particles, thus are drawn into the water as turbidity increases. FIB levels were also higher at and around high tide. This study suggests that sophisticated mathematical models can be constructed to integrate testing parameters. As more variation around these parameters is explained through modeling, then fewer key parameters could be measured in the future, thus reducing the costs for monitoring programs.

140 POLYPHENOL EFFECT ON SUSCEPTIBILITY OF OXIDIZED β-AMYLOID PEPTIDE TO INSULIN DEGRADING ENZYME

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Oxidized amyloid-β proteins (Aβ) play an important role in the pathogenesis of Alzheimer's disease and are the cause of neuronal deaths. This study tested whether polyphenols, antioxidants in green tea, had an effect on the susceptibility of oxidized Aβ to protease digestion by insulin-degrading enzyme (IDE), a major Aβ-degrading enzyme. 2 sets $A\beta_{40}$ peptides were oxidized with NBS and Cu++/ H_2O_2 in either green tea extract, a major source of polyphenols, or aqueous solvent. The Aβ peptides were lyophilized and resuspended and then desalted using C18 spin columns. A BCA protein assay was used to determine the recovery of Aβ from the columns. Green tea and non-green tea incubated $A\beta_{40}$ were subjected to proteolysis with IDE or trypsin. Aβ samples were electrophoresed and were analyzed by Western Blot and the results were captured on x-ray film. This study concludes that IDE and trypsin's proteolytic ability towards oxidized $A\beta_{40}$ incubated in green tea are increased as compared to standard oxidized $A\beta_{40}$. Both enzymes also exhibited increased proteolsis towards the $A\beta_{40}$ peptides when higher concentrations of enzymes were added to the sample. Polyphenols in green tea were able to reduce or prevent the oxidation of $A\beta_{40}$, thus allowing enzymes to degrade the peptides without complications.

141 EFFECTS OF SALINITY CONCENTRATION ON RATES OF POLYP CLONING, GROWTH, AND STROBILATION IN THE *AURELIA LABIATA* (CNIDARIA, SCYPHOZOA)

Julie A. Guerin. Cabrillo Marine Aquarium, San Pedro, CA 90731; (Palos Verdes Peninsula High School, Rolling Hills Estates, CA 90274)

The purpose of this study was to determine how increased and decreased salinity concentrations affect the developmental asexual stage in the life cycle of the *Aurelia labiata.* This species of jellyfish is known to be adaptable in the changing marine environments of coastal ecosystems, but environmental factors could influence their reproduction rates. After culturing from fertilized eggs, 10 similarly

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ANNUAL MEETING OF THE SOUTHERN CALIFORNIA ACADEMY OF SCIENCES

DRESCHER GRADUATE CAMPUS OF PEPPERDINE UNIVERSITY, MALIBU, CALIFORNIA

May 12–13, 2006

FIRST CALL FOR SYMPOSIA AND PAPERS

The Southern California Academy of Sciences will hold its annual Meeting for 2006 on the Drescher Graduate Campus of Pepperdine University on Friday and Saturday May 12–13.

The meeting will be held in conjunction with the California Estuarine Research Society (CAERS) and the Society of Environmental Toxicology and Chemistry (SETAC). Both these societies will hold symposia in addition to those listed below.

Presently the following symposia are in the planning stages. If you would like to organize a Symposia for this meeting, or have suggestions for a symposia topic, please contact John Dorsey at jdorsey@; mu.edu or Brad Blood at bblood@psomas.com. Organizers should have a list of participants and a plan for reaching the targeted audience.

Proposed Symposia for 2006

Southern California Archaeology: Andrea Murray; amurray@exchange.fullerton.edu

Ecology of Nearshore Reefs: Daniel Pondella; pondella@oxy.edu and Bob Grove; grovers@sci.com

Avian biology; Kathy Keane; keanebio@cs.com

Southern California Paleontology: Mark Roeder; mroeder1@earthlink.net

Additonal Symposia on Marine Protected Areas, Parasitology, Red Tides, Fresh Water Vertebrates and Urban Watershed—runoff have been proposed and are in early planning stages.

Contributed Papers and Posters: Both professionals and students are welcome to submit abstracts for a paper or poster in any area of science. Abstracts are required for all papers, as well as posters, and must be submitted in the format listed on the society webpage. Maximum poster size is 32 x 40 inches.

In addition to the Symposia, there will be additional sessions of **Invited Papers and Posters and papers by the Junior Academy members.** The Poster Session will occur on Friday afternoon and early evening while invited papers will be on both Friday and Saturday.

Abstracts of presented papers and posters will be published as a supplement to the August issue of the Bulletin.

Student Awards: Students who elect to participate are eligible for best paper or poster awards in the following categories: ecology and evolution, molecular biology,genetics and physiology, and physical sciences. In addition the American Institute of Fishery Research Biologists will award best paper and poster in fisheries biology. A paper by any combination of student and professional co-authors will be considered eligible provided that it represents work done principally by student(s). In the case of an award to a co-authored paper, the monetary award and a sone year student membership to the Academy will be made to the first author only.

For further information on posters, abstracts, registration and deadlines, see the Southern California Academy of Science web page at http://scas.jsd.claremont.edu/

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Habitat Partitioning by Three Species of Dolphins in Santa Monica Bay, California

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Abstract.—Habitat partitioning by bottlenose dolphins (*Tursiops truncatus*), short-beaked common dolphins (*Delphinus delphis*), and long-beaked common dolphins (*D. capensis*), were assessed during 178 surveys conducted between 1997–2000 in Santa Monica Bay, California. Bottlenose dolphins were found year-round within 0.5 km from shore in 80.0 % of the sightings (n = 137) but they were also found in deeper waters further offshore. The two common dolphin species were observed year-round (n = 83) far from shore and near escarpments; they were sympatric but never seen in mixed schools. This study suggests that habitat partitioning in the bay probably relates to resource partitioning among three dolphins species with roughly similar ecological needs.

Interspecific investigations of odontocete behavioral ecology are rare (Polacheck 1987; Selzer and Payne 1988; Shane 1994; Gowans and Whitehead 1995) and no such studies have been conducted in the Southern California Bight. Studies in Santa Monica Bay (Fig. 1; Bearzi 2005) have found that it is inhabited year-round by three relatively abundant cetaceans: the bottlenose dolphin (*Tursiops truncatus*), the short-beaked common dolphin (*Delphinus delphis*), and the long-beaked common dolphin (*D. capensis*). This investigation examines spatial distribution and habitat partitioning of these three species in the bay between 1997–2000.

Similar species that co-occur are thought to compete for resources unless they occupy different physical locations and/or feed on different prey (Roughgarden 1976). Along the California coast, short-beaked and long-beaked common dolphins are seldom seen close to shore, whereas populations of bottlenose dolphins occur inshore year-round (Carretta et al. 1998; Forney and Barlow 1998; Hansen 1990; Defran and Weller 1999). The genus *Delphinus* has been observed associated with characteristic offshore bathymetric features such as escarpments and submarine canyons (Evans 1974; Polacheck 1987; Selzer and Payne 1988; Gaskin 1992; Gowans and Whitehead 1995). This study correlates the distributions of bottlenose dolphins, short-beaked common dolphins and long-beaked common dolphins with the environmental features of Santa Monica Bay to describe habitat use and inter-specific aggregations of these species.

Species Distributions

The genus *Tursiops* is found widely in temperate and tropical waters. Populations of bottlenose dolphins are known to inhabit pelagic waters as well as coastal

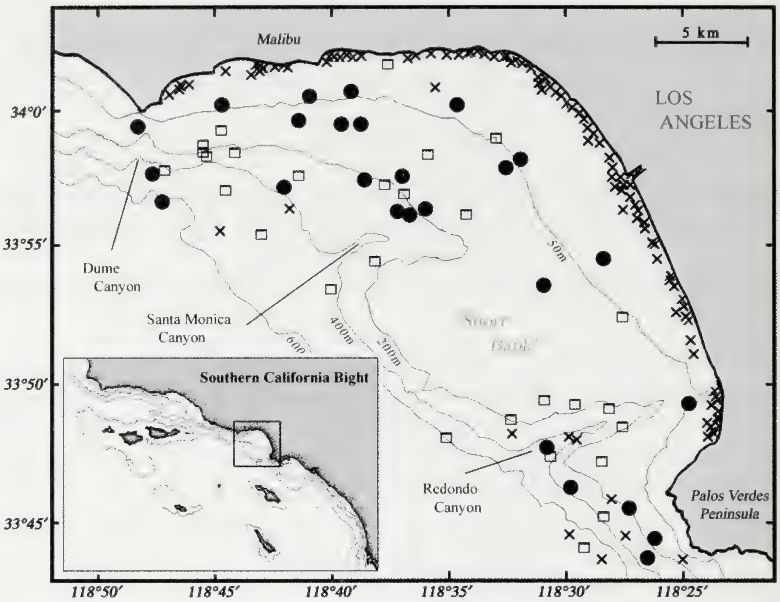

Fig. 1. The study area and the distribution of bottlenose dolphins (×), short-beaked common dolphins (●), and long-beaked common dolphins (□) in the bay. Each symbol represents initial GPS coordinates of sightings. Sightings outside the bay and sightings of *Delphinus* spp. not recognized at the species level were excluded from this map. Submarine canyons (Dume, Santa Monica, Redondo) and escarpments/slopes (Palos Verdes continental slope, west of Los Angeles slope, south of Malibu montain slope) include respectively sightings located no farther than 0.4 km from each side of the canyons and the isobaths, and 1.8 km from the centers of the slopes. Flat areas and plateaus include all the sightings observed in these locations. Submarine canyons are indicated by the three lines.

areas, including bays and tidal creeks (Leatherwood et al. 1983). These populations also show morphological, osteological and molecular differentiations (LeDuc and Curry 1998; Rossbach and Herzing 1999). Coastal forms of bottlenose dolphins exist in many areas of the world (e.g., Shark Bay, Western Australia: Connor and Smolker 1985; the Firth of Tay, Scotland: Wilson 1995; Sarasota Bay, Florida: Scott et al. 1990; Wells 1991; Argentine Bay, Argentina: Würsig 1978; Croatia, Mediterranean Sea: Bearzi et al. 1999). Coastal populations usually live within 0.5 km of shore in schools of 1–25 individuals, sometimes residing in a specific area, while pelagic populations are found in larger groups of 25 to several thousand individuals ranging widely in the open ocean (Scott and Chivers 1990; Bearzi et al. 1999; Defran and Weller 1999; Bearzi 2005).

Long-term studies on free-ranging bottlenose dolphins in the Southern California Bight have been focused mostly along the San Diego coastline (less than 1 km from shore; Defran and Weller 1999). In 1996, a preliminary series of cetacean surveys in the waters of Santa Monica Bay determined that bottlenose dolphins could be found there in all seasons (Bearzi 2005).

Common dolphins (*Delphinus* spp.) also have a wide distribution in tropical and temperate waters. In the eastern North Pacific, there are two separate species of common dolphins, the short-beaked and the long-beaked common dolphin, distinguished morphometrically by Heyning and Perrin (1994) and genetically by

Rosel et al. (1994). In the Southern California Bight the two species occur sympatrically (Heyning and Perrin 1994; Rice 1998).

These dolphins usually live in large schools that can reach thousands of individuals (Cockcroft and Peddemors 1990; Klinowska 1991). Evans (1975) and Bruno et al. (2002), however, suggested that the basic social unit for common dolphins contains less than 30 individuals. Information on occurrence, distribution, and abundance have been collected for this genus in central and southern California (Evans 1975; Dohl et al. 1986; Forney and Barlow 1998), but no information on these animals was previously available for Santa Monica Bay.

Materials and Methods

Study Area

The Santa Monica Bay study area (approximately 460 km^2, Fig. 1) is a shallow shelf bounded by the Palos Verdes Peninsula to the South (33°45′N, 118°24′W), Point Dume to the North (33°59′N, 118°48′W) and the edge of the continental shelf to the West. The bottom habitat of the bay includes sandy soft sediments inshore and silts along slopes and canyons. This study area contains three submarine canyons: Dume and Redondo canyons begins in shallow water, whereas Santa Monica Canyon begins at a depth of about 100 m at the edge of the continental shelf. A shallow shelf, known as "short bank", located between Santa Monica Canyon and Redondo Canyon extends as a plateau from the 50-m contour and is characterized by patchy areas of exposed bedrock, rock pinnacles, gravel, and mixed sediments (Terry et al. 1956). The mean depth of the bay is about 55 m and the maximum depth 450 m. Normal water surface temperatures range from 11 to 22°C. During the 1997–98 El Niño, three peaks of sea surface temperature (SST) anomalies, with an increase in temperature of +2°C, were evident in May–June 1997, September–October 1997 and August 1998 (Nezlin et al. 2003).

Data Collection and Analysis

Regular surveys were conducted from January 1997 to December 2000 (Table 1), with an average of 3.5 surveys per month ($n = 178$). Inshore and offshore surveys, defined respectively as surveys conducted at a distance from shore ≤ 0.5 km and at a distance offshore >0.5 km, were carried out from a 7-m powerboat in the morning and early afternoon.

The number of kilometers surveyed in all different locations of the bay—including submarine canyons (Dume, Santa Monica, Redondo), escarpments/slopes (Palos Verdes continental slope, west of Los Angeles slope, south of Malibu montain slope), flat areas and plateaus—was calculated to determine the evenness in the coverage of the study area using a grid comprised of 82 3.7 × 3.7 km cells (Bearzi 2003). Using Student's t-test for independent samples, no significant difference was observed in surveying the different locations ($t = 1.92$, $df = 28$, $P > 0.05$). Differences in distribution among species in relation to the bathymetry of the bay were evaluated comparing their positions (initial GPS coordinates of dolphin sightings) among eight different isobaths from 0 to 600 m using a finer grid comprised of 2.5 × 2.5 km cells and calculating the total number of sightings in each cell (Bearzi 2003).

Data were collected with laptop computers and occasionally with tape record-

Table 1. Number of surveys, summary of research effort, and sighting frequencies (sightings/hour) of the three most observed cetacean species in Santa Monica Bay between 1997–2000.

	1997	1998	1999[a]	2000[b]	Total
Surveys					
Inshore surveys	5	17	12	6	40
Offshore surveys	23	3	5	4	35
Combined inshore/offshore surveys	11	38	27	27	103
Total number of surveys	39	58	44	37	178
Research Effort					
Hours spent in the field	144	224	178	149	695
Hours spent searching for dolphins	110	136	130	105	481
Hours spent with the three species	26	80	53	41	200
Hours spent with *Delphinus* spp.	9	17	18	19	63
Hours spent with *T. truncatus*	17	63	35	22	137
Sightings*	29	87	57	47	220
Tursiops truncatus					
Number of sightings	19	61	33	24	137
Sighting frequency (sightings/hour)	0.13	0.27	0.19	0.16	0.20
Delphinus spp.**					
Number of sightings	10	26	24	23	83
Sighting frequency (sightings/hour)	0.07	0.12	0.14	0.15	0.12
Delphinus capensis					
Number of sightings	2	13	11	10	36
Sighting frequency (sightings/hour)	0.01	0.06	0.06	0.07	0.05
Delphinus delphis					
Number of sightings	6	7	6	6	25
Sighting frequency (sightings/hour)	0.04	0.03	0.03	0.04	0.04
N of 5-min samples	295	1,065	698	525	2,583

[a, b] no data collection in Dec 1999 and Oct 2000.
* one mixed school of different species is counted as one sighting.
** this calculation includes *Delphinus* spp. not recognized at the species level.

ers. When dolphins were spotted, data on number of animals and behavior were recorded at 5-min intervals throughout the sighting (Bearzi 2003).

The majority of the observations were conducted with Beaufort scale 2 or less, sea state 0 and visibility >300 m. The dolphins' position and speed (±30 m from the boat) were approximated to the boat's position using a GPS. The boat's speed was reduced in the presence of dolphins and sudden speed or directional changes were avoided.

To distinguish between short-beaked and long-beaked common dolphins, researchers took close-up photographs of the animals' lateral foresection. Color photos were taken with 35-mm cameras equipped with 75–300-mm lenses using slide film (64-200 ISO). During the sighting, researchers also videotaped the animals' lateral foresections and recorded their behavior with Hi8-mm and Mini DV Video Camcorders. Photos and videos were reviewed in laboratory for the species identification based on body features described by Heyning and Perrin (1994).

A *dolphin school* was defined as all dolphins in continuous association with each other and within visual range of the survey team (Weller 1991). *Aggregation* referred to distances between one or more individuals of two different species being less than 100 m.

Data analyses were performed using Statview 5.02 and Grapher 3.02; data on species distribution were plotted with Arcview GIS 3.2 and Surfer 6.02.

Results

Field Effort

Data were collected during 40 inshore surveys, 35 offshore surveys, and 103 combined inshore/offshore surveys in the bay; the survey coverage between 1997 and 2000 totaled 9,526 km. A total of 446 h were spent searching for cetaceans in good weather conditions (Beaufort scale ≤ 2) and 35 h in unfavorable conditions (Beaufort scale >2). A total of 137 h (64.0 % of total sighting time) were spent with bottlenose dolphins during 137 sightings, lasting on average 64 min (range 3–262 min), and a total of 63 h (29.4 % of total sighting time) were spent with short-beaked and long-beaked common dolphins during 83 sightings, lasting on average 51 min (range 5–185 min; Table 1).

Occurrence, Sighting Frequencies and Distribution

Bottlenose dolphins were most frequently sighted year-round (62.3 % of the sightings; n = 220) generally inshore (80.0 %), followed by long-beaked and short-beaked common dolphins (respectively 16.4 % and 11.4 % of the sightings; Table 1, Fig. 2a). The two species of common dolphins were spotted only eight times (9.6 %) in inshore waters.

Sightings/effort for the three species in the years 1997–2000 and during different seasons are illustrated in Figs. 2a,b,c. Long-beaked common dolphins were slightly more abundant than short-beaked common dolphins in the years 1998–2000, although the difference in sighting number was not significant among the four years (long-beaked common dolphins: 59.0 %, short-beaked common dolphins: 41.0 %, n = 61; $\chi^2 = 1.33$, df = 1, $P > 0.05$; Table 1).

The distribution of the three species in relation to the bathymetry is presented in Fig. 1. Species distribution differed significantly according to depth ($\chi^2 = 92.09$, df = 7, $P < 0.001$), with bottlenose dolphins inhabiting mostly inshore waters (0–50 m deep) and the two species of common dolphins being more frequent in deeper waters. The distribution of short-beaked common dolphins versus long-beaked common dolphins also differed significantly with depth ($\chi^2 = 21.19$, df = 7, $P < 0.001$), with short-beaked common dolphins showing a broader distribution, mostly between the 50–100 m isobaths (Fig. 1). All species showed a significant preference for canyons, escarpments, and slopes ($\chi^2 = 22.41$, df = 5, $P < 0.001$). No significant difference was observed between short-beaked and long-beaked common dolphins in terms of their proximity to canyons (Dume, Santa Monica, Redondo) and escarpments/slopes (continental slope, west of Los Angeles slope, south of Malibu mountain slope; $\chi^2 = 1.95$, df = 5, $P > 0.05$; Fig. 1).

Short-beaked and long-beaked common dolphins did not aggregate together, although both species aggregated with other cetaceans. In offshore waters, common dolphins were observed twice in mixed schools with other cetacean species; once with Pacific white-sided dolphins (*Lagenorhynchus obliquidens*), and once with minke whales (*Balaenoptera acutorostrata*). In inshore waters, both common

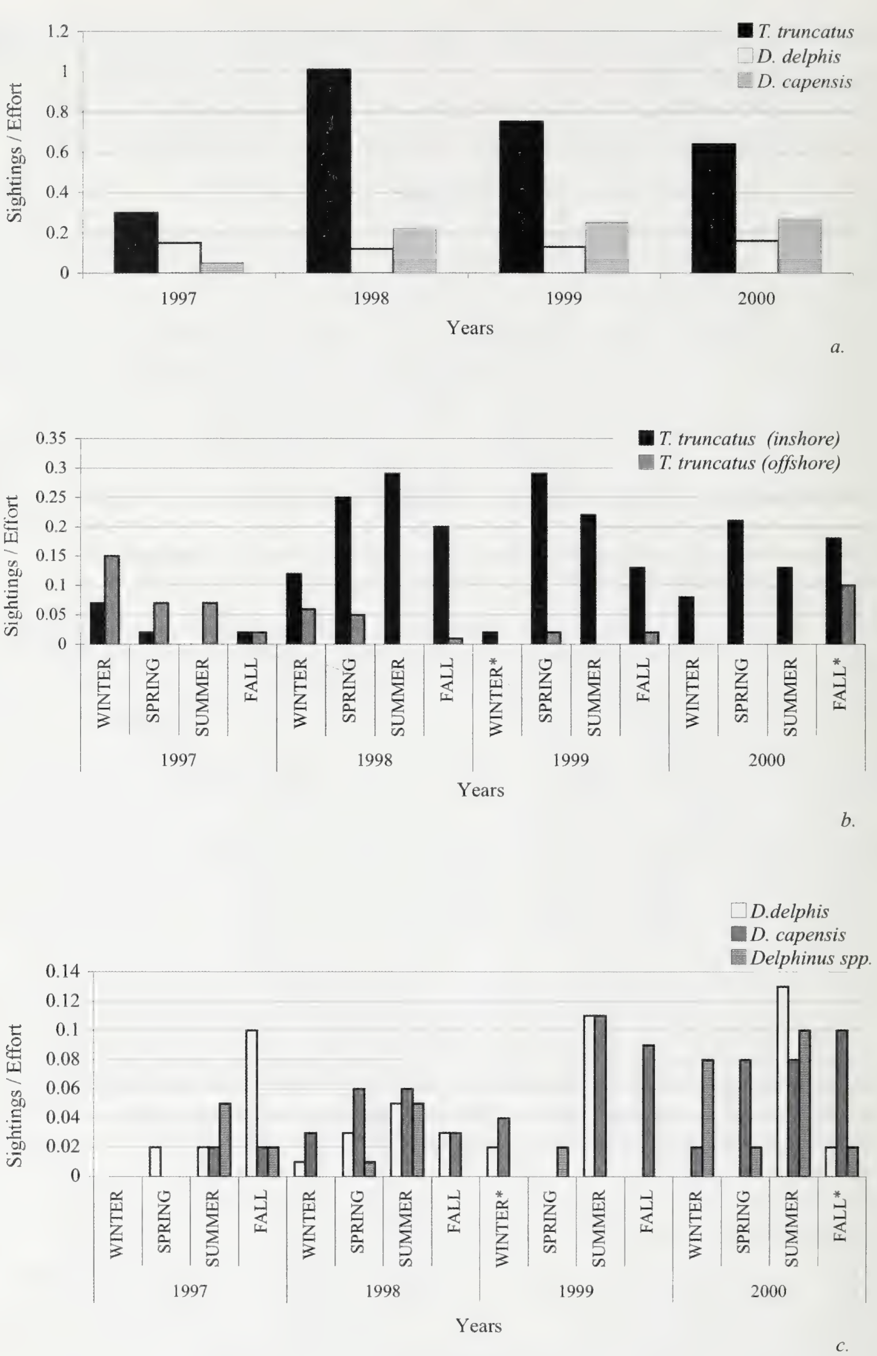

Fig. 2a,b,c. (a) Sightings/effort for the three species observed in the bay during the years 1997–2000, (b) sightings/effort for *T. truncatus* observed during inshore and offshore surveys and, (c) sightings/effort for *D. capensis, D. delphis,* and *Delphinus* spp. (animals recognized only at genus level). In figures 2b,c, the years were divided into four seasonal categories: Winter (December–February), Spring (March–May), Summer (June–August), and Fall (September–November). No data was collected in December 1999* and October 2000*.

dolphin species were observed 87.5 % of the sightings (n = 7) in mixed schools with coastal bottlenose dolphins.

Discussion

Bottlenose dolphins were most often observed in Santa Monica Bay, generally sighted within 0.5 km of shore, as is the case along the San Diego coastline (Defran and Weller 1999). The occurrence of *Delphinus* spp. in Santa Monica Bay was also consistent with reports for other areas of the California coast (Southern California Bight: Norris and Prescott 1961; Leatherwood et al. 1988; Bonnell and Dailey 1993; California coast: Forney and Barlow 1998). In the bay, both species of common dolphins were sighted year-round and mostly offshore with similar distributions.

Long-term studies on inshore bottlenose dolphins suggest that their distribution may be related to the distribution and abundance of nearshore prey (Defran and Weller 1999). Stomach content show that 74.0 % of their prey were either surfperches (*Embiotocidae*) or croakers (*Scianidae*) (Norris and Prescott 1961; Walker 1981; Hanson and Defran 1993). These prey species occur year-round in shallow coastal waters of the Southern California Bight (Cross and Allen 1993). The year-round abundance of bottlenose dolphins in Santa Monica Bay may be explained by a year-round presence of nearshore prey (Deets and Roney 1999; California Department of Fish and Game 2000; Bearzi 2005).

The more-offshore sightings of short-beaked and long-beaked common dolphins may be related to different prey preferences (Table 2). For short-beaked common dolphins, Evans (1975) found their main prey in the Bight was anchovies (*Engraulis mordax*) whereas Fitch and Brownell (1968) and Schwartz et al. (1992) reported that squid (family *Gonatidae* and *Loligo opalescens*) and Pacific whiting (*Merluccius productus*) were their primary prey. All these prey species are primarily pelagic inhabitants of the Bight (California Department of Fish and Game 2000). In Santa Monica Bay, therefore, inshore bottlenose dolphins and the two species of common dolphins differ both in distribution and prey preference. I suggest that the habitat partitioning of these species is a consequence of prey specialization and competition for resources in inshore waters.

The three species distributions did overlap, however near Redondo Canyon and the continental slope south of Palos Verdes Peninsula (Fig. 1); these areas are the deepest and steepest features in the bay (Dartnell and Gardner 2004). Upwelling of highly oxygenated and nutrient-rich water was found over the San Pedro shelf and eddy-like features near the slopes in the southern half of Santa Monica shelf were also observed (Hickey 1992, 1993). These oceanographic features are optimal for mixing of nutrients that would provide rich feeding grounds for dolphins. Anchovies are known to concentrate in submarine canyons and escarpments in areas of upwelling (Mais 1974; Hui 1979). This potential abundance of prey was likely to allow the three species to coexist in the same areas.

Other locations of the bay near canyons, escarpments and slopes show a significantly higher number of sightings than flat areas and plateaus. These results show interesting parallels with white-sided dolphins (*Lagenorhynchus acutus*) and short-beaked common dolphins along the continental shelf of northeastern United States (Selzer and Payne 1988), and various odontocetes near a submarine canyon on the Scotian Shelf (Gowans and Whitehead 1995). Other authors have also

Table 2. Diet of *T. truncatus* and *Delphinus* spp. in Southern California waters. N = nearshore prey, O = offshore prey, B = prey present in both, inshore and offshore waters (e.g., different seasons, different life stages, etc.).

Prey	Habitat	*T. truncatus*[1]	*Delphinus* spp.[2]
Walleye surfperch (*Hyperprosopon argenteum*)	N	X	
Pile surfperch (*Damalichthys vacca*)	N	X	
Black surfperch (*Embiotoca jacksoni*)	N	X	
Shiner surfperch (*Cymatogaster aggregatus*)	N	X	
White surfperch (*Phanerodon furcatus*)	N	X	
Barred surfperch (*Amphistichus argenteus*)	N	X	
Blacksmith (*Chromis punctipinnis*)	N	X	
Spotfin croaker (*Rancador stearnsi*)	N	X	
Kelp bass (*Paralabrax clathratus*)	N	X	
Smelts (*Osmeridae*)	N	X	X
Queenfish (*Seriphus politus*)	N	X	X
California halibut (*Paralichthys californicus*)	B	X	
Yellowfin croaker (*Umbrina rancador*)	B	X	
White croaker (*Genyonemus lineatus*)	B	X	
California corbina (*Menticirrhus undulates*)	B	X	
Specklefin midshipman (*Porychthys myriaster*)	B	X	
Octopoteuthidae	B	X	
Plainfin midshipman (*Porychthys notatus*)	B	X	X
Cusk eel (*Ophidiidae*)	B	X	X
Jack mackerel (*Trachurus symmetricus*)	B	X	X
Northern anchovy (*Engrualis mordax*)	B	X	X
Market squid (*Loligo opalescens*)	B	X	X
Sardine (*Sardinops coerulea*)	B		X
Pacific mackerel (*Scomber japonicus*)	B		X
Pacific whiting (*Merluccius productus*)	O		X
Northern lampfish (*Stenobrachius leucopsarus*)	O		X
Bonito (*Sarda chiliensis*)	O		X
California Smoothtongue (*Bathylagus stilbius*)	O		X
Pacific pompano (*Peprilus simillimus*)	O		X
Lanternfish (*Myctophidae*)	O		X
Medusafish (*Icichthys lockingtoni*)	O		X
Onychoteuthidae	O		X
Gonatus sp.	O		X

[1] Walker 1981; Hanson and Defran 1993 (for coastal populations). Data from stomach contents.

[2] Norris and Prescott 1961; Fitch and Brownell 1968; Evans 1975; Schwartz et al. 1992; Bonnell and Dailey 1993; M. Bearzi pers. obs. Data from stomach contents and fish scale collection.

reported the presence of the genus *Delphinus* along sea floor reliefs, submarine canyons and escarpments (Evans 1974; Hui 1979; Polacheck 1987; Selzer and Payne 1988; Gaskin 1992; Gowans and Whitehead 1995), showing that undersea topography, rather than water depth, is the most significant physical feature influencing the distribution of common dolphins.

In Santa Monica Bay, the two species of common dolphins have the same preference for the same escarpments, slopes and submarine canyons, but short-beaked common dolphins show a less-defined distribution, predominantly between the 50–100 m isobaths. The year-round co-occurrence of these species in the study area over four years may be related to productive feeding grounds, rich enough in prey to support their feeding requirements. This is suggested by the relatively high amount of time spent feeding or diving (about 30.0 % of total time; Bearzi

2003) in comparison to data reported by Neumann (2001) for the Bay of Plenty, New Zealand (17.0 % of total time).

Shifts in abundance of long-beaked and short-beaked common dolphins were observed since the last century in southern California waters (Banks and Brownell 1969; Heyning and Perrin 1994). In this study, long-beaked common dolphins were the more common in the bay starting from 1998, at the end of the 1997–1998 El Niño, showing a pattern similar to the one previously observed by Heyning and Perrin (1994). These authors suggested that environmental factors may be more advantageous to one or the other species at different times. However, differences in habitat use between short-beaked and long-beaked common dolphins are complex, considering the similar diet of the two species (Fitch and Brownell 1968; Schwartz et al. 1992; Ohizumi 1998). In the southern California waters, stomach content analyses showed that short-beaked common dolphins feed more on squid, a prey usually caught at depth during the day or at surface at night, than do long-beaked common dolphins (Schwartz et al. 1992). Decreased squid abundance during the last two El Niño events (California Department of Fish and Game 2000) could partially explain the greater number of short-beaked common dolphins before both El Niño events and the decrease in number after these events.

Although short-beaked and long-beaked common dolphins were both sighted in similar locations of the bay, confirming a sympatric micro-range, no occurrence of these two taxonomically close species in mixed schools was ever observed. The slight difference in diet could indicate a separation of ecological niches reducing the occurrence of direct competition for food resources when the dolphins are sympatric. Different preferences in prey for sympatric dolphins were observed by other authors (Das et al. 2000; Hale et al. 2000). Gowans and Whitehead (1995) explained the co-occurrence of species either by a superabundance of food or by a slightly different diet that may eliminate a competitive pressure between the species.

Conclusions

Spatial habitat partitioning by different dolphin species has rarely been described in detail (Selzer and Payne 1988; Gowans and Whitehead 1995). This study provides a description of habitat partitioning by three species of dolphins in Santa Monica Bay. Bottlenose dolphins were found year-round in shallow waters, clearly separated from the distribution of short-beaked and long-beaked common dolphins, but they were also observed occasionally in deeper waters over the continental shelf and pelagic waters outside the bay. Short-beaked and long-beaked common dolphins were found year-round in the bay but mostly far from shore. Both common dolphin species were sighted in areas of complex underwater topography. Although they were observed in similar locations of the bay, confirming their sympatric range, these two species were never seen in mixed schools.

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Dry-season Water Quality in the San Gabriel River Watershed

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Abstract.—Dry-season flow in the San Gabriel River system is comprised mostly of discharges from water reclamation plants (WRPs), imported water, and storm drains. Although the magnitude of dry-season discharge is generally known, the water quality associated with most of these "introduced" discharges has not been characterized, nor has the associated in-stream response, particularly near storm drain discharges. The goal of this study was to characterize the pattern and magnitude of storm drain and WRP inputs to the San Gabriel River system and the associated in-stream response. To accomplish this, two synoptic dry-weather surveys were conducted, one in 2002 and the other in 2003 during which flow, metals, bacteria, and nutrient concentrations were measured from the WRPs, storm drains, and in-stream locations at a single point in time. For bacteria and most metals, storm drains accounted for the majority of mass emissions to the river. In contrast, WRPs were the primary source for nutrients. In-stream water quality concentrations generally reflected the main sources. For example, in-stream ammonia concentrations were highest downstream of WRP discharges. In-stream bacteria concentrations were consistently high and showed no apparent spatial pattern, suggesting that storm drains or other in-stream sources are present throughout the watershed.

Urbanization has had many consequences on the hydrology of southern California's coastal watersheds (Hamilton 1992; Schuler and Holland 2000; Roesner and Bledsoe 2003). Streams historically convey seasonal storm flows and are dry for large portions of the year. Today, large engineered channels have replaced most large streams and rivers to accommodate increases in storm water runoff. In addition, the historical intermittent hydroperiod has been replaced by year-round baseflow.

In the San Gabriel watershed, the large engineered channels that predominate in the lower watershed receive dry-weather flow from a variety of "introduced" sources, such as water reclamation plant (WRP) discharges, other National Pollutant Discharge Elimination System (NPDES) discharges, storm drain discharges of non-point source runoff from the developed landscape, and imported water that is conveyed seasonally through the San Gabriel River and its tributaries to spreading grounds located throughout the watershed.

Dry-season sources of water may include a suite of urban-generated constituents that have the potential to affect surface water quality adversely. For example, storm drains have been found to be the primary source of pollutants in the neighboring Los Angeles River watershed (Ackerman et al. 2003). Also, Bay et al. (1996) found that dry-weather runoff to the Santa Monica Bay contained toxic levels of certain constituents. Previously, documented concentrations of nutrients, metals, and bacteria have resulted in large portions of the lower San Gabriel watershed being listed as impaired under Section 303(d) of the Clean Water Act.

Managing dry-season water quality requires an understanding of the water quality associated with the primary sources of dry-weather flow (i.e., storm drains and WRP discharges), and the relationship between these sources and in-stream water quality. Although hundreds of storm drains discharge to the 303(d) listed portions of the San Gabriel River and its tributaries, the spatial and temporal patterns of these inputs relative to those of the WRPs have not been quantified. Furthermore, the relative mass contribution of pollutants from storm drains and WRP discharges has not been investigated, nor has the response of in-stream water quality to these mass loadings.

The goal of this study is to characterize storm drain and WRP inputs to the San Gabriel River system and the associated in-stream response. The relative contribution of non-point source (i.e., storm drain) and point source (i.e., WRP) inputs were quantified for bacteria, metals, and nutrients. The observed concentrations also were compared to existing water quality standards in order to provide managers with information that can be used in developing strategies to address water quality impairments.

Methods

This study is comprised of two parts. The first part consists of identifying and sampling the major inputs to the San Gabriel River and its major tributaries. The second part is comprised of sampling the in-stream water quality to assess spatial water quality patterns and the relationship between sources and in-stream water quality. Two synoptic surveys were conducted approximately one year apart during which approximately 85 storm drains and 16 in-river sites were sampled twice over a 2-day period each year.

Watershed

The 1,866 km^2 San Gabriel River (SGR) watershed (Figure 1) is highly urbanized in its lower portions, and predominantly undeveloped in the upper watershed. The reaches that are listed as having impaired water quality and are the focus of this study are San Gabriel River, Coyote Creek (CC), San Jose Creek (SJC), and Walnut Creek (WC) (Table 1). Any storm drains, channels, or other discharges to these reaches were considered inputs to the system.

Flow through the SGR system is highly managed by diversions and concrete and rubber dams that route water to various infiltration areas. As a result, dry-weather flows are highly variable both within and between years (LACDPW 2004). For example, in Water Year (WY) 2002–03, the Los Angeles County Department of Public Works (LACDPW) imported 1.02×10^8 m^3 of water (LACDPW 2004) and conveyed much of that water through the SJC and WC systems to spreading grounds. In that same year, 7.01×10^6 m^3 of water from the San Jose Creek and Pomona WRPs was sent to spreading grounds, while 1.40×10^7 m^3 was allowed to pass to the ocean (LACDPW 2004). The earthen bottom portions of the SGR are used for infiltration; therefore, although physically connected, the WC and SJC are often hydrologically discontinuous from the SGR during dry-weather conditions (Figure 2).

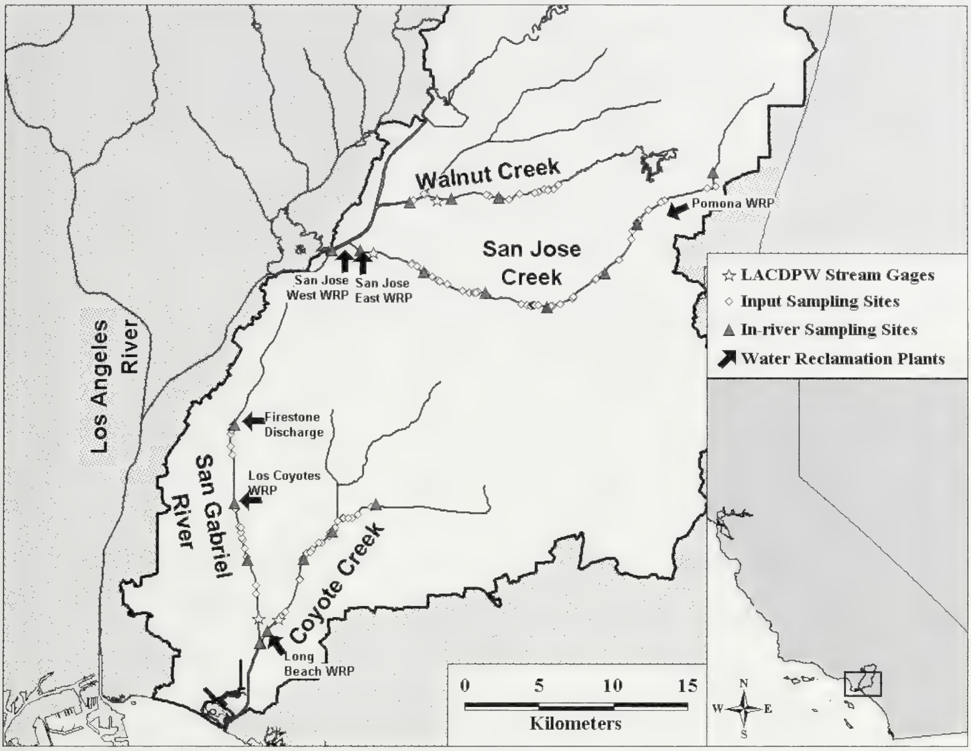
Walnut Creek
Pomona WRP
San Jose Creek
San Jose West WRP
San Jose East WRP
☆ LACDPW Stream Gages
◇ Input Sampling Sites
▲ In-river Sampling Sites
Water Reclamation Plants
Los Angeles River
San Gabriel River
Firestone Discharge
Los Coyotes WRP
Coyote Creek
Long Beach WRP
0 5 10 15
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Fig. 1. Map of the San Gabriel River watershed. Shown are the impaired streams, storm drain locations during the two surveys, in-stream sampling points, stream gages and water reclamation plant discharge locations.

Input Sampling

Inputs to the SGR watershed were sampled on September 29, 2002 and September 14, 2003. Point source inputs included four WRPs that discharge tertiary treated wastewater. The Los Coyotes WRP discharges to the SGR, the Long Beach WRP discharges to the CC, and the Pomona WRP discharges to the SJC. The San Jose Creek WRP discharges to both the SJC and SGR. The WRP effluent was collected as a 4-hour composite sample and analyzed for the parameters listed in Table 2.

Inputs that convey non-point source discharge were sampled synoptically during each of the two sampling events. Non-point source inputs were classified as either "small storm drain" discharges or "large NPS" discharges. The latter consisted mainly of open channels that drain to the impaired reaches that are the focus of this study (Table 3). Prior to each sampling event, storm drains and large NPSs were surveyed to identify those that flow during the dry season. At each flowing storm drain or large NPS, flow was measured using either timed-volumetric or depth-velocity methods (as appropriate, given the conditions at the location). Water quality samples were collected directly by filling the sample bottle or using a sterilized scoop to collect the water sample. Samples were placed on ice and transported to the laboratories for analysis of the parameters listed in

Table 1. List of stream impairments and their lengths for the San Gabriel Watershed.

	Length (km)	Impairment
San Gabriel River	41	Algae, coliform, dissolved copper, lead, dissolved zinc, toxicity, abnormal fish histology
Coyote Creek	21	Algae, coliform, dissolved copper, dissolved lead, total selenium, dissolved zinc, toxicity, abnormal fish histology
San Jose Creek	32	Algae, coliform
Walnut Creek	19	Toxicity, pH

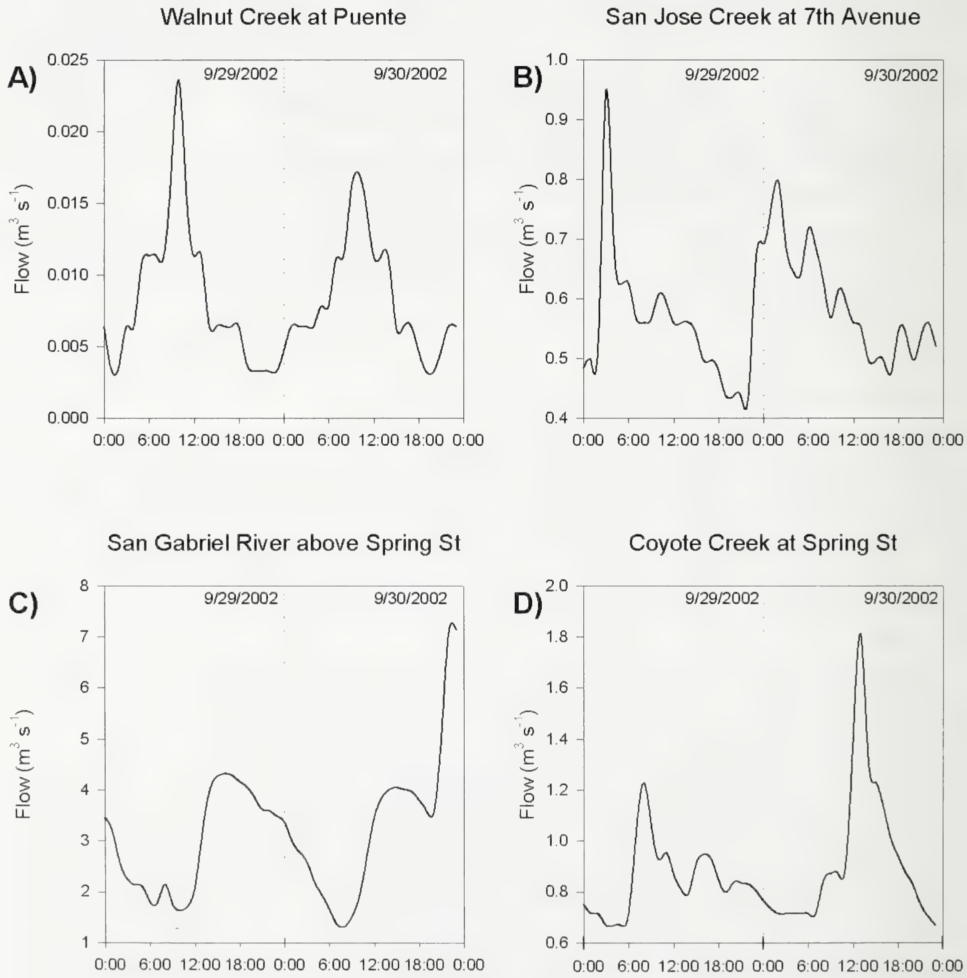

Fig. 2. In-stream flow variability for the 2002 sampling survey by stream.

Table 2. Constituents sampled during each survey along with the analytical method used and the reporting limit.

		Analytical Method	Reporting Limit
Bacteria	*Enterococcus*	Quanti-Tray	10 MPN/100mL
	E Coli	Quanti-Tray (2003)	10 MPN/100mL
	Fecal Coliform	Membrane Filtration (2002)	10 MPN/100mL
	Total Coliform	Quanti-Tray	10 MPN/100mL
Generals	Hardness	EPA 130.2 - titration	2 mg/L
	pH	EPA 150.1	N/A
	TSS	EPA 160.2 - GF/C filtration	2 mg/L
Metals	Aluminum	EPA 200.7 - ICP/AES	50 ug/L
	Arsenic	SM 3114 B4d - hydride generation	1 ug/L
	Cadmium	EPA 213.2 - Stabilized temperature platform furnace	0.4 ug/L
	Chromium	EPA 200.7 - ICP/AES	10 ug/L
	Copper	EPA 200.7 - ICP/AES	8 ug/L
	Iron	EPA 200.7 - ICP/AES	50 ug/L
	Lead	EPA 239.2 - Stabilized temperature platform furnace	2 ug/L
	Nickel	EPA 200.7 - ICP/AES	20 ug/L
	Selenium	SM 3114 B - hydride generation	1 ug/L
	Zinc	EPA 200.7 - ICP/AES	10 ug/L
Nutrients	Ammonia	SM 4500 NH3E - titrimetric distillation	100 ug/L
	Nitrate-Nitrite	EPA300.0/SM 4500NO2 B - ion chromotography	50 ug/L
	TKN	SM 4500 NorgB - organic N digestion + titrimetric distillation	100 ug/L
	Dissolved Phosphorus	EPA 365.3 - spectrophotometric	50 ug/L
	Total Phosphorus	EPA 365.3 - spectrophotometric	50 ug/L
Pesticides	Diazinon	ELISA	0.05 ug/L

Table 2. The analytical methods and reporting limits for each constituent are listed in Table 2.

In-stream Sampling

The day after the storm drain sampling (September 30, 2002 and September 15, 2003), in-stream water quality samples were taken from each of the four study streams. Samples were taken at the upstream boundary of each reach, at the most downstream point, and at points between to characterize water quality changes (14 locations in total) (Figure 1). Six additional sites were added in 2003 to better resolve longitudinal in-stream water quality. Composite samples were collected by taking three grab samples over a 10-min period. A second composite sample was collected 20 min later, and a third composite was collected 40 min after the initial composite. The three samples were analyzed separately to characterize the short-term in-stream variability. Flow information was obtained from existing flow gages maintained by the Los Angeles County Department of Public Works.

Data Analysis

Flow and water quality data were analyzed for spatial and temporal patterns. Means and ranges of flow and concentration for all locations were analyzed by

Table 3. Large non-point source (NPS) discharges to the impaired reaches of the San Gabriel River Watershed.

Receiving Water Reach	Large NPS Discharge
Coyote Creek	Carbon Creek Brea Creek Fullerton Creek La Mirada Wash
San Jose Creek	Lemon Creek Diamond Bar Wash Puente Creek
Walnut Creek	Big Dalton Wash (includes San Dimas and Little Dalton Wash)

individual sampling date and compared between sampling dates. Constituent loads were calculated by multiplying flow times concentration for each sample, as described in Schiff (1997):

$$\mathit{Load} = \sum \mathrm{F}_i\mathrm{C}_i$$

where F_i was the flow and C_i was the constituent concentration at location *i.* When multiple samples were averaged, results are presented as means ± the 95% confidence interval. In all cases, nondetectable results were assigned a value of zero.

Results

One hundred storm drains and eight large NPS discharges were sampled over the two sampling periods. During the 2002 survey, 87 storm drains were sampled and the majority of those storm drains were in the SJC (Table 4). In 2003, 84 storm drains were sampled, with 58 of those drains being the same as the ones sampled in 2002. The same 6 large NPS discharges were sampled in both 2002 and 2003.

Table 4. Measured flows (10^6 L d^{-1}) and number of samples by stream reach and source category.

	Coyote		San Gabriel		San Jose		Walnut		Total	
2002	Flow 10^6 L d^{-1}	N	Flow 10^6 L d^{-1}	n	Flow 10^6 L d^{-1}	N	Flow 10^6 L d^{-1}	n	Flow 10^6 L d^{-1}	n
Storm Drains	26.0	15	7.5	19	35.0	32	3.0	9	71.4	75
Large NPS	20.3	4	—	0	2.5	1	14.7	1	37.4	6
WRPs	0.1	1	238.5	2	142.7	3	—	0	381.2	6
TOTAL	46.3	20	246.0	21	180.1	36	17.7	10	490.1	87
	Coyote		San Gabriel		San Jose		Walnut		Total	
2003	Flow 10^6 L d^{-1}	n	Flow 10^6 L d^{-1}	N	Flow 10^6 L d^{-1}	N	Flow 10^6 L d^{-1}	n	Flow 10^6 L d^{-1}	n
Storm Drains	29.0	16	3.9	10	33.0	33	4.2	13	70.1	72
Large NPS	18.2	4	—	0	16.3	1	9.6	1	44.0	6
WRPs	45.8	1	255.5	2	213.5	3	—	0	514.8	6
TOTAL	93.0	21	259.4	12	259.4	37	13.8	14	629.0	84

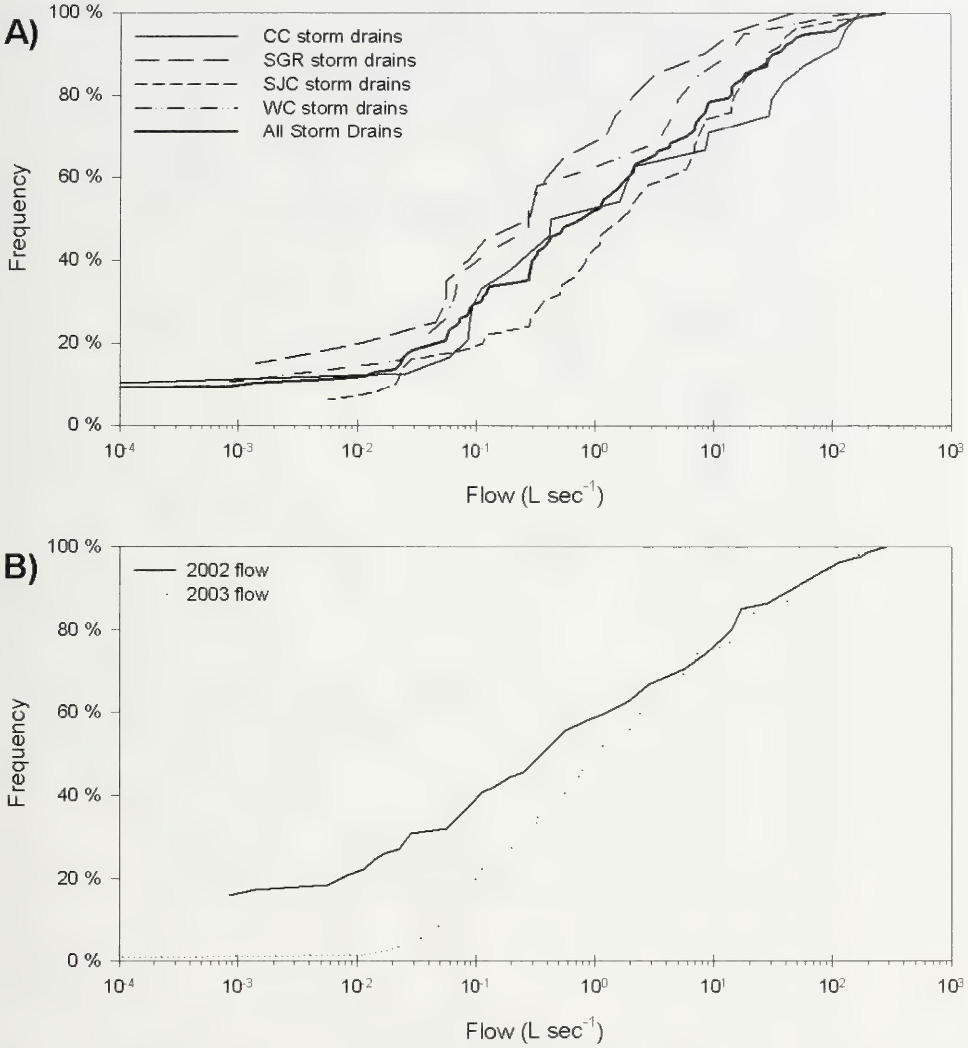

Fig. 3. Distribution of observed storm drain flows by sampled stream (A) and by survey for all flowing storm drains sampled in the SGR watershed (B).

Flow

Nearly 80% of measured flow in the SGR watershed was from the WRPs during both surveys (Table 4). The majority originated from the San Jose Creek WRP, and discharged either to the confluence of San Jose Creek and San Gabriel River or through a pipeline that discharged to the San Gabriel River 16 km downstream of the confluence. Over 80% of the storm drains and large NPS discharges carried flows less than 28 L s^{-1} (1 cfs) (Figure 3). Flows over 5 L s^{-1} comprised the top 30% of the flowing drains and were comparable between the two surveys. Higher proportions of storm drains had small flows (i.e., below 5 L s^{-1}) in 2002 as compared to 2003. These differences at storm drains with very low flow may be due to true interannual variability, but could also be an artifact of the inherent

Table 5. Mean of observed concentrations and 95th percent confidence interval by source. Geometric means are reported for bacteria samples; arithmetic means are reported for all other constituents. Nondetectable samples were assumed to be zero. Note that in 2002 Fecal Coliforms were measured, whereas in 2003 *E. coli* was measured.

			Storm Drains		Large NPS Discharges		WRPs	
2002 Results		MDL	Average	95% C.I.	Average	95% C.I.	Average	95% C.I.
Bacteria								
Enterococcus	MPN/100mL	10	17,600	15,300	29,400	55,400	ND	—
Fecal Coliforms	MPN/100mL	10	1,210	1,290	2,990	20,500	0.26	0.72
Total Coliforms	MPN/100mL	10	177,000	198.000	1,020,000	2,460,000	2.13	4.89
Metals								
Hardness	mg/L	2	356	39.1	368	84.2	199	21.7
Chromium	ug/L	10	0.14	0.28	1.67	3.27	ND	—
Copper	ug/L	8	15.0	7.36	7.00	6.52	ND	—
Iron	ug/L	50	572	281	1,940	3,360	44.2	30.4
Lead	ug/L	2	2.60	1.21	3.00	2.15	ND	—
Nickel	ug/L	20	7.39	4.71	ND	—	ND	—
Zinc	ug/L	10	134	83.1	28.3	22.3	45.0	8.39
Nutrients								
Ammonia-N	mg/L	0.01	0.77	0.47	0.05	0.07	8.01	3.01
Nitrate-Nitrite	mg/L	0.03	3.36	1.53	0.49	0.54	3.00	1.26
TKN	mg/L	0.02	3.16	1.21	1.62	0.53	9.41	3.15
Total Phosphate-P	mg/L	0.05	0.50	0.10	0.08	0.06	0.72	0.27

Table 5. Continued.

			Storm Drains		Large NPS Discharges		WRPs	
2003 Results		MDL	Average	95% C.I.	Average	95% C.I.	Average	95% C.I.
Bacteria								
Enterococus	MPN/100ml	10	650	658	1,660	363	ND	—
E. coli	MPN/100mL	10	10,400	9,070	9,080	4,500	0.93	5.09
Total Coliforms	MPN/100mL	10	21,800	21,400	29,900	11,400	ND	—
Metals								
Hardness	mg/L	2	343	4.09	408	80.2	190	18.9
Chromium	ug/L	10	ND	—	ND	—	ND	—
Copper	ug/L	8	8.00	3.30	3.00	3.10	ND	—
Iron	ug/L	50	394	138	453	203	36.84	36.0
Lead	ug/L	2	1.57	0.63	1.92	1.12	ND	—
Nickel	ug/L	20	0.69	1.36	ND	—	ND	—
Zinc	ug/L	10	99.3	22.7	57.1	13.3	72.4	7.08
Nutrients								
Ammonia-N	mg/L	0.01	0.33	0.34	0	—	1.40	0.35
Nitrate-Nitrite	mg/L	0.03	2.87	1.53	1.96	2.55	3.00	0.73
TKN	mg/L	0.02	1.86	0.59	1.67	0.56	2.62	0.46
Total Phosphate-P	mg/L	0.05	0.45	0.11	0.10	0.05	0.43	0.16
Diazinon	ng/L	50	122	77.6	83.9	38.7	No data available	

variability associated with measuring storm drain flows, which increases dramatically in drains with low discharge.

Water Quality

The mean concentration of water quality constituents varied by source (Table 5). The WRPs had the highest nutrient concentrations (e.g. 3.0 mg/L of nitrate-nitrite vs. 0.03 mg/L for storm drains). Storm drains and large NPS discharges had the highest bacteria concentrations (e.g. 10^4–10^5 MPN/100 ml of total coliforms vs. $<10^1$ MPN/100ml for WRPs). Metal concentrations were generally higher in the storm drain and large NPS discharges than from WRPs, but there were some differences based on individual metals. In general, metals concentrations were lower in large NPS discharge tributaries than in small storm drains.

Concentrations and loads from WRP and non-point source inputs generally were higher in 2002 than in 2003. For example, total coliform concentrations from storm drains and large NPS discharges were between 10 and 30 times higher in 2002 than in 2003, while loads were between 9 and 50 times higher in 2002 (Figure 4). Similarly, fecal coliform loads in 2002 were up to 40 times higher than *E. coli* loads in 2003. Assuming fecal coliforms are comprised of approximately 80% *E. coli,* the loads would still have been more than 30% higher in 2002 than in 2003. Metals concentrations were also higher in 2002 (with the exception of zinc), but were typically within the same order of magnitude during both surveys. Overall, daily loads of copper were 2 times higher in 2002 than in 2003; however, in 2002 small storm drains accounted for a substantially lower proportion of copper relative to large NPS discharges than in 2003 (Figure 4). Bacteria and metals data were approximately the same for the WRPs between the two surveys. However, nutrient concentrations were generally 50% lower during the 2003 survey, due to operational changes at the WRPs.

Source Comparison to Standards

Water quality from the storm drains frequently exceeded water quality standards for bacteria. The bacteria levels observed in storm drain flows (Figure 5) exceeded water quality standards in 98% of the sampled drains. In contrast, in-river metals concentrations never exceeded the hardness-adjusted acute water quality standards under the California Toxics Rule (CTR; Figure 6). Although the CTR generally applies only to receiving waters and not to storm drain or NPS discharges, such a comparison is instructive for identifying potentially problematic discharges. In general, storm drain and large NPS discharges were also below CTR standards, except for copper, which exceeded acute CTR standards in 4% to 8% of the storm drain and large NPS inputs; and zinc, which exceeded chronic CTR standards in 2% to 8% of the storm drain and large NPS inputs (Figures 5 and 6, Table 6).

Mass Emission

The major pollutant sources to the SGR watershed differed by constituent (Table 7). The WRPs contributed approximately 90% or more of the nutrient mass loadings to the system. In contrast, almost all bacteria loading was contributed by storm drains and large NPS discharges. In 2002, the eight large NPS discharges accounted for over twice as much bacteria load to the system as the small storm drains, despite having less flow. In contrast, in 2003, the bacteria load from large

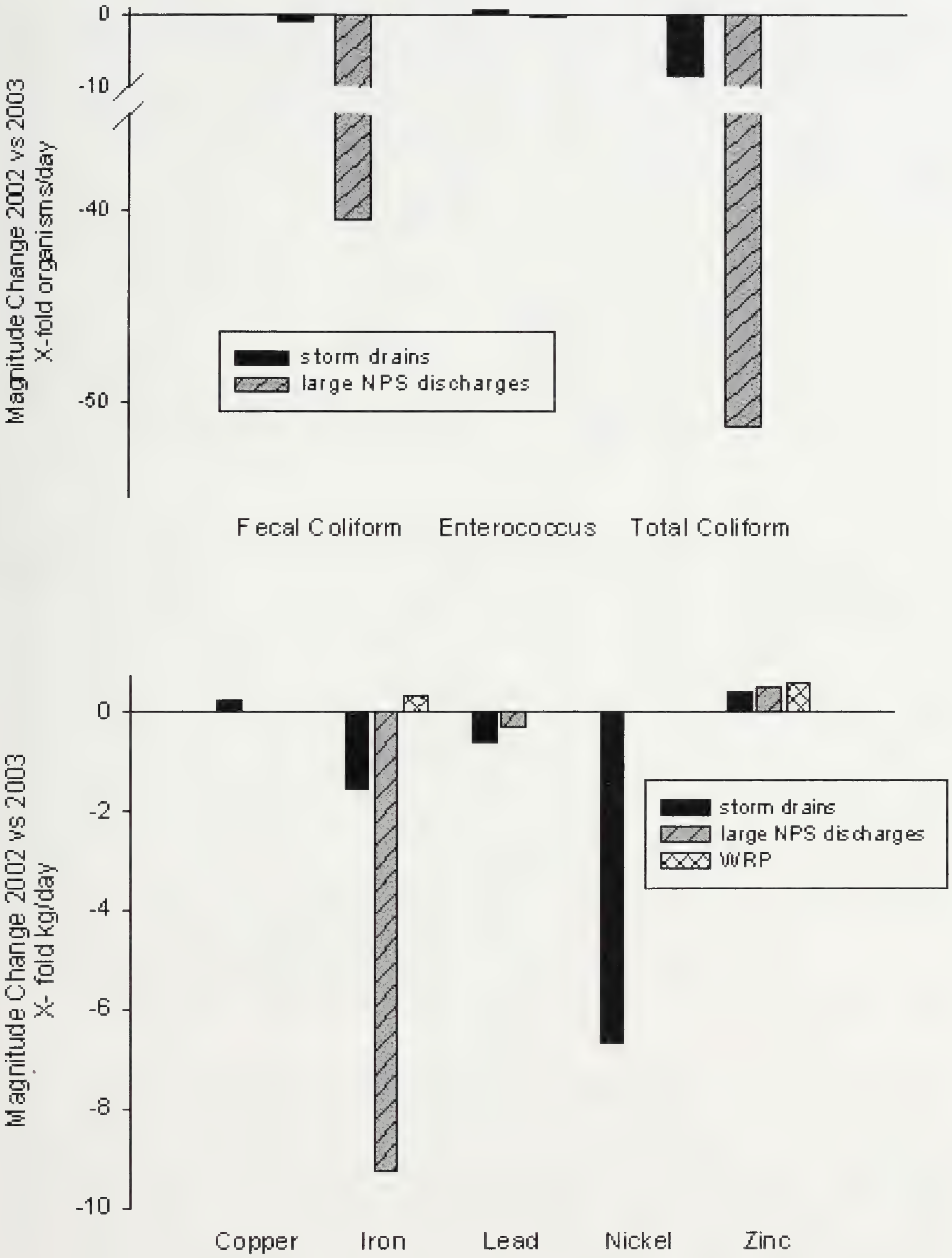

Fig. 4. Comparison of daily loads between 2002 and 2003 for bacteria (top) and metals (bottom). Values are in magnitude difference. Bars below the line indicate higher loads in 2002; bars above the line indicate higher loads in 2003.

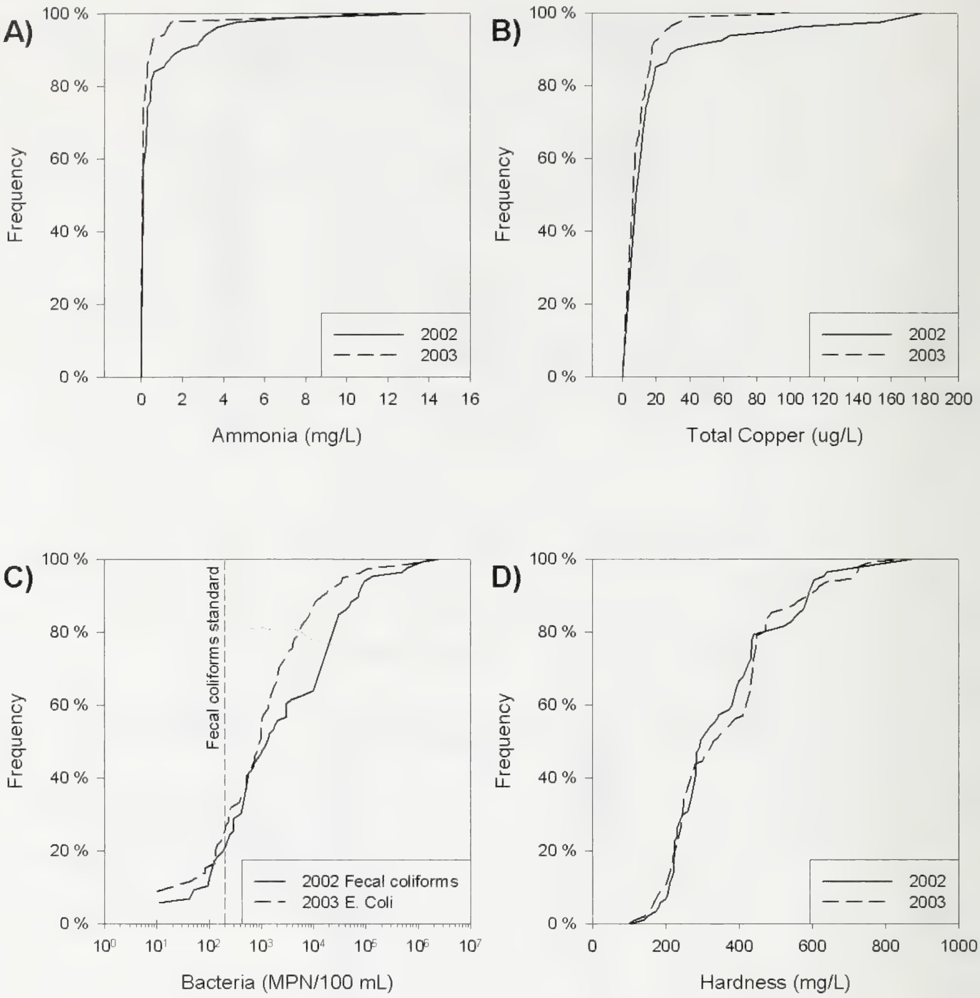

Fig. 5. Distribution of observed storm drain water quality concentrations by year.

NPS discharges was lower than that from small storm drains. The relative mass emission of trace metals varied by source and by metal. In 2002, the large NPS discharges accounted for twice as much copper, iron, and lead relative to the small storm drains; in 2003, copper and iron emissions were higher in small storm drains than in the large NPS discharges. In both years, loadings of copper, lead, and nickel from the WRPs was minimal; however, the WRPs contributed the majority of zinc loading and between 12% and 51% of lead loading.

Coyote Creek and the San Gabriel/San Jose Creek confluence area received the greatest mass loadings of pollutants of the four streams (Table 8). The large bacteria loading to Coyote Creek reflected the large storm drain volumetric inputs (Table 4). Large nutrient loadings in the SJC corresponded to large volumetric discharges from the San Jose WRP (214×10^6 L d^{-1} in 2002). Walnut Creek received no WRP input and had volumetric loadings less than half of the CC and SJC. Despite its low flow relative to other portions of the system, bacteria loadings

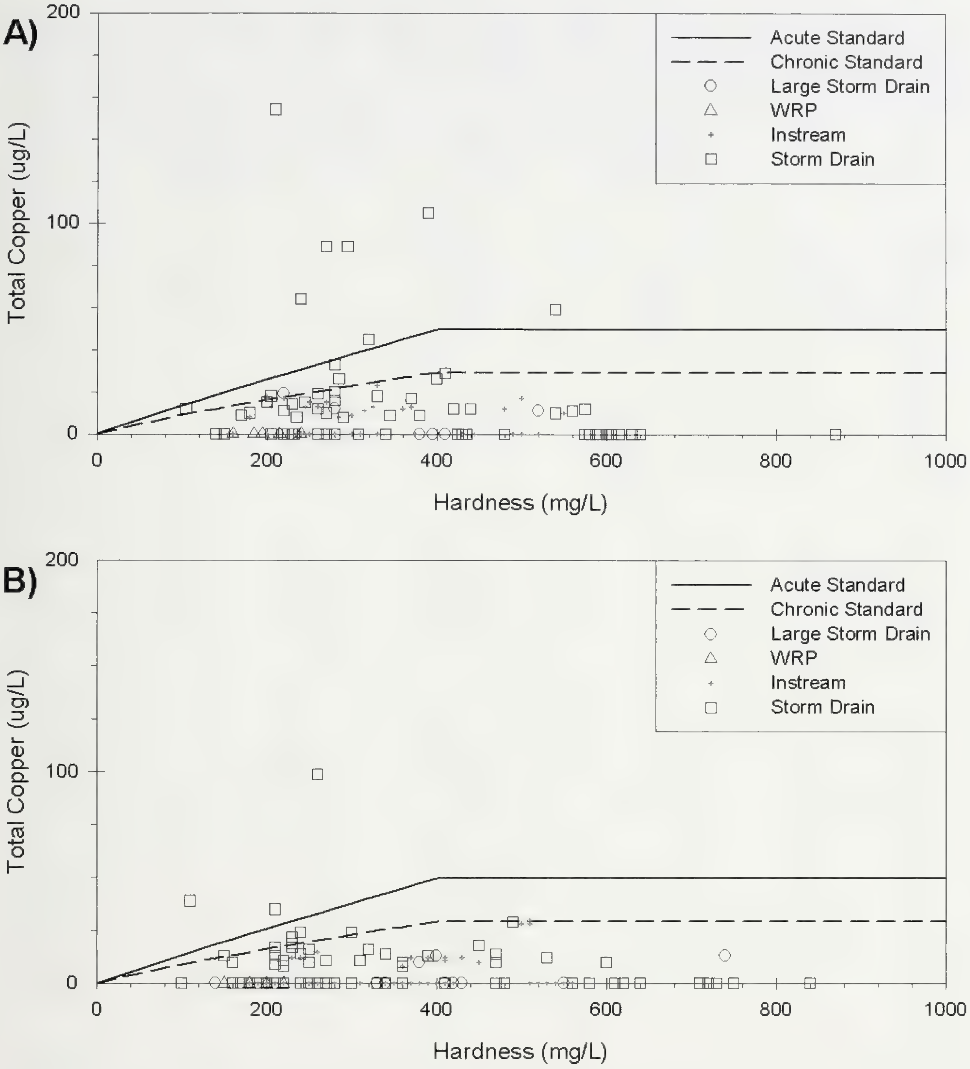

Fig. 6. Measured hardness-dependent copper toxicity by source and year.

Table 6. Percent of all samples (i.e., storm drains, large non-point source inputs, and WRP discharges) that exceeded the hardness-adjusted acute and chronic California Toxics Rule (CTR) metals criteria by year.

	Acute Criteria		Chronic Criteria	
	2002	2003	2002	2003
Cadmium	1%	0%	1%	0%
Chromium	0%	0%	0%	0%
Copper	5%	2%	10%	7%
Lead	0%	0%	2%	3%
Nickel	0%	0%	0%	0%
Silver	0%	0%	0%	0%
Zinc	5%	1%	5%	1%

Table 7. Total mass emission by source for the two dry-weather sampling events. Samples with non-detectable values are treated as zero.

			Percent Contribution		
Consituent	Total Mass Emissions	Units	Storm Drains	Large NPS Discharges	WRPs
2002					
Bacteria					
Fecal Coliforms	1,800	$(10^9)\ hr^{-1}$	34%	66%	0%
Enterococcus	948	$(10^9)\ hr^{-1}$	35%	65%	0%
Total Coliforms	48,300	$(10^9)\ hr^{-1}$	28%	72%	0%
Metals					
Copper	0.0285	$kg\ hr^{-1}$	38%	62%	0%
Iron	7.94	$kg\ hr^{-1}$	30%	58%	12%
Lead	0.0083	$kg\ hr^{-1}$	29%	71%	0%
Nickel	0.0023	$kg\ hr^{-1}$	100%	0%	0%
Zinc	0.79	$kg\ hr^{-1}$	14%	8%	78%
Nutrients					
Ammonia-N	87.6	$kg\ hr^{-1}$	1%	0%	99%
Nitrate-Nitrite	69.1	$kg\ hr^{-1}$	5%	1%	94%
TKN	113	$kg\ hr^{-1}$	3%	2%	95%
Total Phosphorous	7.67	$kg\ hr^{-1}$	8%	1%	90%
2003					
Bacteria					
E. coli	800	$(10^9)\ hr^{-1}$	91%	9%	0%
Enterococcus	1,110	$(10^9)\ hr^{-1}$	58%	42%	0%
Total Coliforms	2,090	$(10^9)\ hr^{-1}$	68%	32%	0%
Metals					
Copper	0.014	$kg\ hr^{-1}$	100%	0%	0%
Iron	2.81	$kg\ hr^{-1}$	33%	16%	51%
Lead	0.0060	$kg\ hr^{-1}$	25%	75%	0%
Nickel	0.0003	$kg\ hr^{-1}$	100%	0%	0%
Zinc	1.74	$kg\ hr^{-1}$	11%	7%	82%
Nutrients					
Ammonia-N	26.6	$kg\ hr^{-1}$	1%	0%	99%
Nitrate-Nitrite	66.6	$kg\ hr^{-1}$	8%	2%	90%
TKN	57.9	$kg\ hr^{-1}$	7%	3%	89%
Total Phosphorous	7.19	$kg\ hr^{-1}$	6%	4%	89%

from Walnut Creek in 2003 nearly equaled those in the CC and SJC. High loadings in WC are attributed mainly to high in-stream concentrations, which are more than 200% higher than those of the other streams.

In-stream Concentrations

The spatial distribution of pollutants throughout the four reaches in the SGR watershed reflects the influence of major mass emission sources (Figures 7–9). For nutrients, in-stream ammonia levels in the SJC and the SGR were markedly higher downstream of the Pomona, San Jose Creek, and Los Coyotes WRPs (Figure 7). Where storm drains were the only inputs; i.e., upper Coyote Creek and Walnut

Table 8. Total mass emission by creek for the two dry-weather sampling events.

			Percent Contribution			
Consituent	Total Mass Emissions	Units	Coyote Creek	San Gabriel River	San Jose Creek	Walnut Creek
2002						
Bacteria						
Fecal Coliforms	1,800	(10^{9}) hr^{-1}	66%	5%	17%	12%
Enterococcus	948	(10^{9}) hr^{-1}	62%	20%	10%	7%
Total Coliforms	48,300	(10^{9}) hr^{-1}	62%	14%	16%	8%
Metals						
Copper	0.0285	kg hr^{-1}	22%	12%	20%	46%
Iron	7.94	kg hr^{-1}	58%	9%	31%	2%
Lead	0.0083	kg hr^{-1}	55%	14%	8%	24%
Nickel	0.0023	kg hr^{-1}	9%	50%	36%	0%
Zinc	0.79	kg hr^{-1}	8%	53%	36%	3%
Nutrients						
Ammonia-N	87.6	kg hr^{-1}	0%	55%	45%	0%
Nitrate-Nitrite	69.1	kg hr^{-1}	2%	67%	31%	0%
TKN	113	kg hr^{-1}	2%	55%	42%	1%
Total Phosphorous	7.67	kg hr^{-1}	5%	54%	41%	0%
2003						
Bacteria						
E. coli	315	(10^{9}) hr^{-1}	36%	0%	28%	35%
Enterococcus	1,110	(10^{9}) hr^{-1}	40%	4%	44%	11%
Total Coliforms	2,090	(10^{9}) hr^{-1}	33%	2%	49%	15%
Metals						
Copper	0.014	kg hr^{-1}	49%	2%	29%	20%
Iron	2.81	kg hr^{-1}	13%	27%	50%	10%
Lead	0.0060	kg hr^{-1}	11%	1%	39%	50%
Nickel	0.0003	kg hr^{-1}	0%	0%	100%	0%
Zinc	1.74	kg hr^{-1}	16%	43%	38%	3%
Nutrients						
Ammonia-N	26.6	kg hr^{-1}	10%	63%	27%	0%
Nitrate-Nitrite	66.6	kg hr^{-1}	10%	53%	36%	1%
TKN	57.9	kg hr^{-1}	14%	53%	31%	2%
Total Phosphorous	7.19	kg hr^{-1}	21%	46%	31%	3%

Creek, nutrient concentrations were consistently low. Bacteria concentrations were generally high throughout all stream reaches, with no apparent spatial pattern (Figure 8). In some cases, metals concentrations appeared to reflect the locations of large inputs. For example, the 2002 in-stream copper concentrations were higher near the locations where large storm drains discharged (Figure 8).

Discussion

The characteristics and patterns of dry-season water quality observed in the SGR watershed are comparable to those seen in the neighboring urbanized watersheds, such as the Los Angeles River (LAR) watershed (Ackerman et al. 2003) and Ballona Creek watershed (Stein and Tiefenthaler 2004). Similar to the LAR,

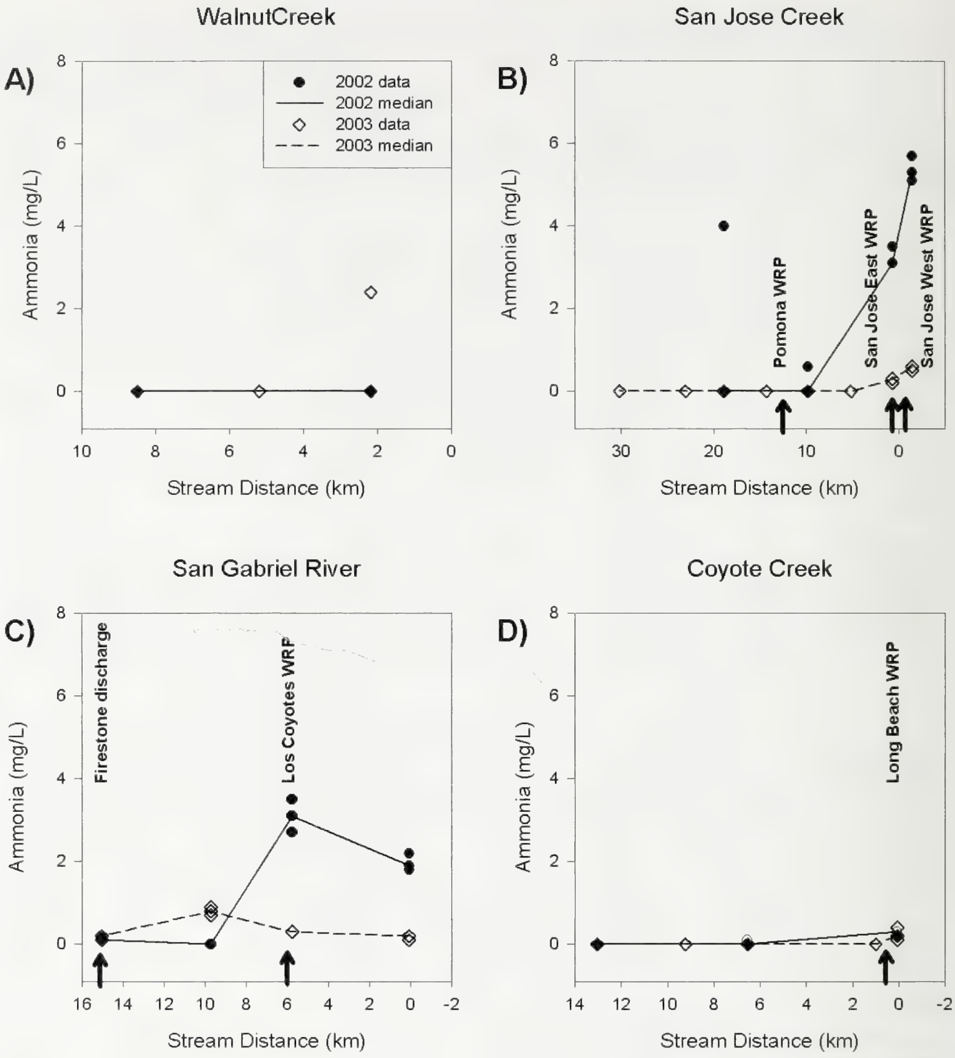

Fig. 7. In-stream ammonia concentrations by stream and year (vertical arrows show WRP locations). In Figure 7b, 0 km is the confluence of San Jose Creek and the San Gabriel River.

the WRPs were determined to be the major source of flow and nutrients (there are no WRP discharges into Ballona Creek). Non-point source discharges are the major source of bacteria in all three watersheds. Similar to the LAR watershed, the source of metals loading varied by individual metal, with storm drains being the predominant source of most metals. In both the LAR and the SGR, WRPs were the predominant source of zinc. Unlike the LAR watershed, however, copper loading resulted primarily from storm drains in the SGR. This difference is likely due to higher detection limits used in the LAR study (e.g. in the LAR study, lead and iron detection limits were 10 and 200 ug/L, respectively and in this study 2 and 50 ug/L), which resulted in many more storm drain samples having "non-detect" values, causing the WRPs to appear to be the major source of copper. This conclusion is further supported by the fact that storm drain concentrations

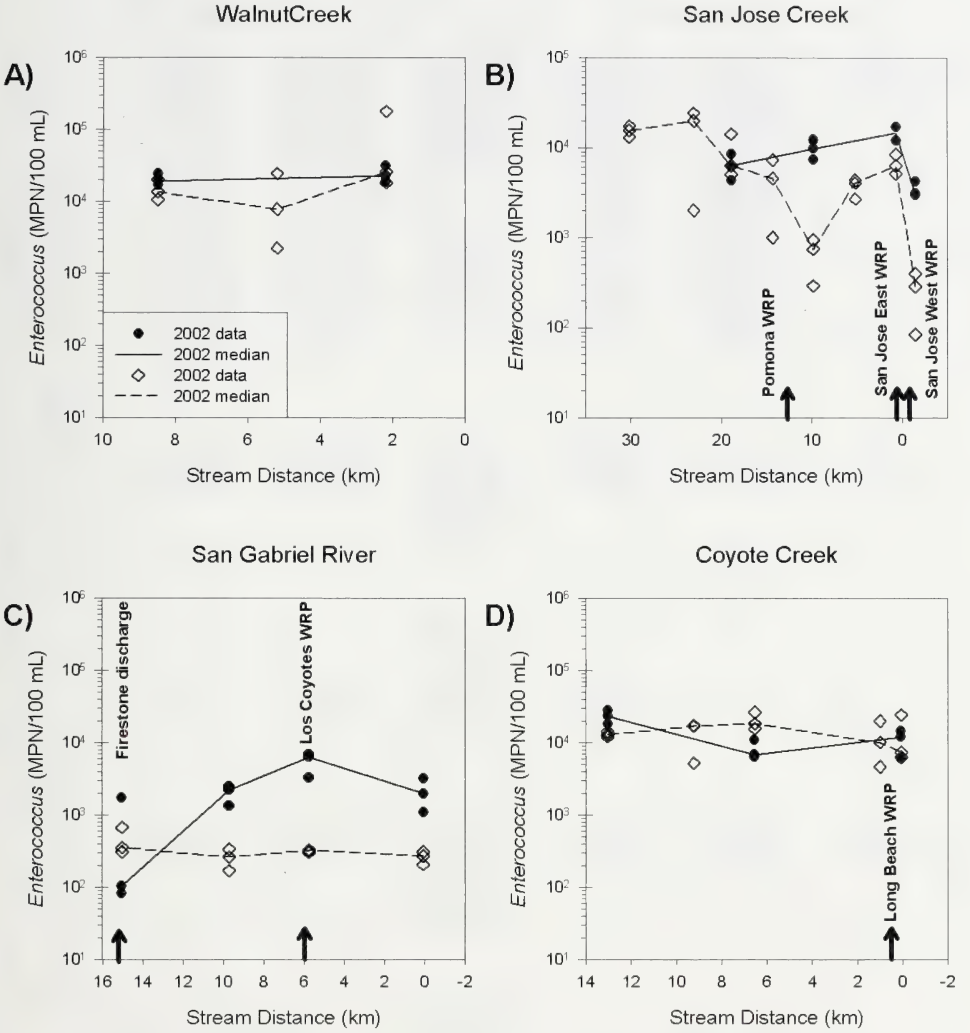

Fig. 8. In-stream *Enterococcus* concentrations by stream and year (vertical arrows show WRP locations). In Figure 8b, 0 km is the confluence of San Jose Creek and the San Gabriel River.

in the SGR were comparable to those observed in Ballona Creek, where detection limits were similar to those used in the SGR.

The manner in which samples with nondetectable levels of a particular metal were treated may affect conclusions regarding distribution of load among sources. The degree that nondetectable values influence general conclusions about loading depends on the frequency of nondetectable values. In our analyses, we assumed that samples below the detection limit had a concentration of zero. Due to the large volume input by the WRPs, small differences in these estimates can have a dramatic effect on the overall distribution of trace metal sources (Figure 10). For example, assuming that nondetectable samples for nickel were equal to a concentration of zero led to an estimation that storm drains account for 100% of the nickel mass. If this assumption were changed to a concentration equal to one-half

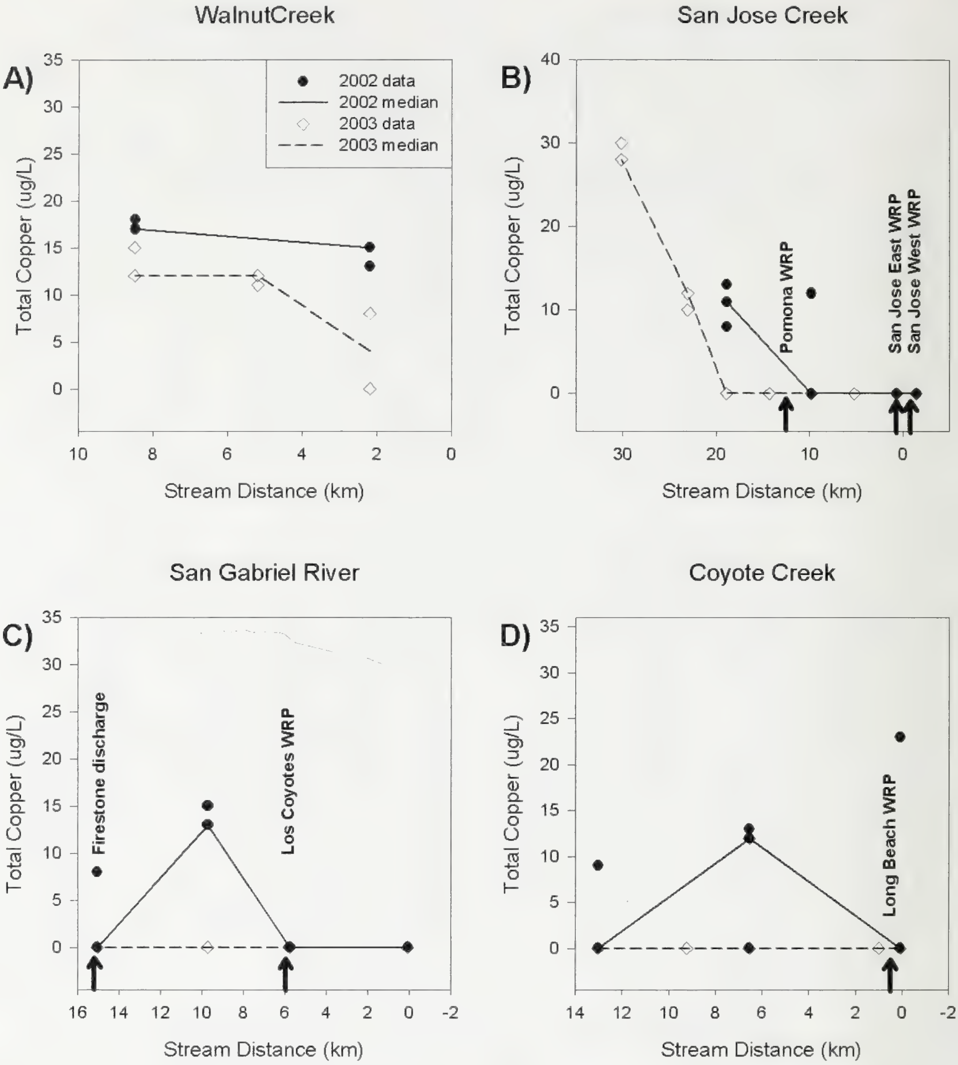

Fig. 9. In-stream copper concentrations by stream and year (vertical arrows show WRP locations). In Figure 9b, 0 km is the confluence of San Jose Creek and the San Gabriel River.

the detection limit, the WRPs would become the dominant source for nickel as well as five of the six other metals analyzed.

Although the magnitude of constituent concentrations varied from year to year, the general spatial patterns were consistent. For example, the ranges of measured storm drain flow and the distribution of flow among storm drains and between streams was generally consistent (Figure 2). Likewise, the pattern of storm drain concentrations for a given class of constituents was consistent between the two sampling events. For example, relatively few drains had high concentrations of metals and nutrients, whereas most drains had high concentrations of bacteria (Figure 4). The ubiquitously high bacteria concentrations reflect a consistent source being generated from the urban land uses in the watershed. Other non-

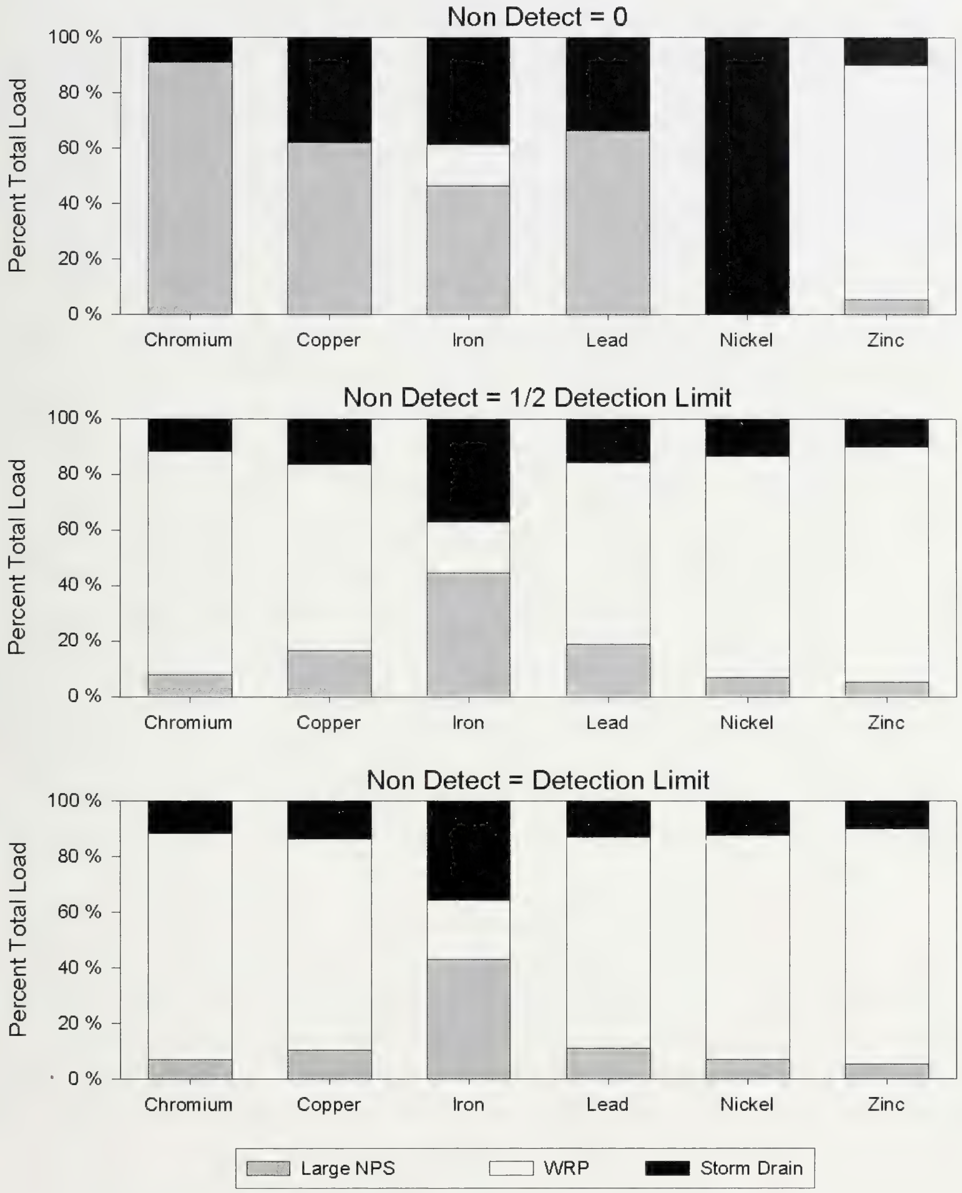

Fig. 10. The effect of detection limits on the aggregated trace metal loadings using data from both sampling events.

human sources, such as horses, birds, and dogs, and in-channel growth likely also contribute to the high levels observed. In general, spatial patterns of in-stream water quality correspond to the locations of dominant discharges for each constituent. For example, in-stream nutrient concentrations were highest downstream of WRP discharges, whereas in-stream metals concentrations were highest downstream of areas where storm drains with high metals concentrations discharged. The consistently high bacteria concentrations throughout the system make establishing linkages between sources and receiving water concentrations more difficult. In addition, potential in-stream sources of bacteria (e.g., birds or regrowth) were not evaluated in this study. Nevertheless, the patterns observed in this study were consistent with those observed in the LAR and Ballona watersheds and generally indicate a direct link between source inputs and in-river concentrations.

Inter-annual variability in metals concentrations was similar to or slightly less than the typical ranges seen in Ballona Creek and LAR (Ackerman et al. 2003). However, inter-annual variations in bacteria concentrations were higher than typically seen in other systems. This may be due to the lack of replication in this study, which would serve to amplify the inherently large fluctuations often seen in bacteria concentrations. Because the goal of this study was to provide a synoptic view of water quality, increased spatial coverage of samples was prioritized over replication at individual locations. Inclusion of such replication would have likely reduced inter-annual variability in bacteria concentrations. Nevertheless, the pattern of high concentration of bacteria in both source inputs and receiving waters was consistent between years.

In contrast, differences in nutrient loading from the WRPs between 2002 and 2003 (and the resultant in-stream concentrations) were a result of changes in treatment practices (Figures 6b and 6c). In the interval between the two surveys, nitrification and denitrification facilities were installed at the WRPs. Decreases in measured average ammonia concentrations in the WRP effluent from 8.01 to 1.40 mg/L between 2002 and 2003 reflect this additional level of treatment. Similarly, in-stream concentrations downstream of the WRP discharges also decreased from 2002 to 2003. For example, the median ammonia concentration downstream of the San Jose Creek WRP decreased from 5.3 to 0.6 mg/L. This significant decrease in ammonia further demonstrates the influence of this source on in-stream water quality.

Conclusions

The results from this study are similar to those seen in the Los Angeles River. Storm drains were the primary source of bacteria and most metals, while the WRPs the main source of nutrients. The instream water quality reflects these inputs and was consistent between the two samplings. The storm drain water quality concentrations and flow were highly variable; however, but variability was similar between the two surveys.

Acknowledgements

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Research Notes

Rediscovery of the Laomediid Shrimp *Naushonia macginitiei* (Glassell, 1938) (Crustacea: Decapoda: Thalassinidea: Laomediidae) from off Southern California

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Introduction

The decapod crustacean genus *Naushonia* Kingsley, 1897, currently contains seven species of rare, burrowing shrimp-like thalassinoids (Goy and Provenzano 1979; Martin and Abele 1982; Berggren 1992; Alvarez *et al.* 2000). Species are known from mud and other soft sediments in temperate and tropical localities worldwide, with the exception of Asia (e.g. *N. crangonoides* from the east coast of the U.S, *N. panamensis* from the Pacific coast of Panama, *N. perrieri* from the Red Sea, *N. lactoalbida* from Moçambique, *N. manningi* from the Bahamas), but in almost all cases each species is known from very few specimens. The sole species known from the west coast of North America is *Naushonia macginitiei* (Glassell), described originally (as *Homoriscus macginitiei*) by Glassell based on two ovigerous females collected from La Jolla, California, in 1935 (Glassell 1938: 414). Soon after the species was described, Chace (1939) reassigned both known species of *Homoriscus* to the genus *Naushonia.* Goy and Provenzano (1979) briefly reviewed the genus *Naushonia* and mentioned a total of four specimens of *N. macginitiei* examined by them (including the ovigerous female paratype) in the collections of the U. S. National Museum of Natural History (USNM). However, Goy and Provenzano (1979) did not provide information on the collecting locality of those specimens, although that information has now been provided to us by the USNM (see below).

To date, the species is known from only two reports in the literature and a total of five specimens, possibly explaining why the species was not listed by Williams et al. (1989) in their list of the known decapod Crustacea from North America (an omission that has now been corrected by McLaughlin *et al.* 2005). In addition to the published reports noted above, additional specimens have been encountered during regional monitoring efforts of the Southern California Coastal Water Research Project (SCCWRP; see www.sccwrp.org). Stations where the species was collected during the SCCWRP Bight 98 project were 2259 (at a depth of 11.2 m; 1 specimen), 2259 (10.9 m; 1 specimen), and 2264 (10.1 m; 2 specimens), all of which were in San Diego Bay. During the SCCWRP Bight 03 project, one specimen was found at each of the following stations: BRI 17 (7 m), BRI 19 (9 m), and 4116 (4 m), with all stations again being in San Diego Bay (Don Cadien and Ananda Ranasinghe, personal communication). Additionally, there are unpub-

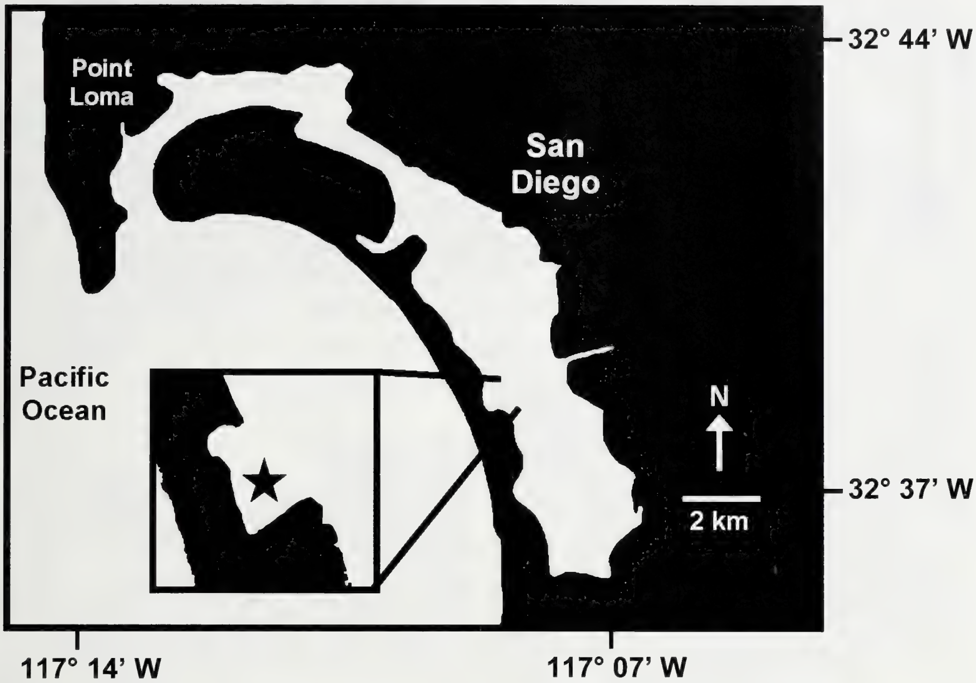

Fig. 1. Map of San Diego Bay with star indicating the location of the eelgrass harvesting experiment and specimen collection site.

lished reports by southern California biologists of laomediid larvae that almost undoubtedly belong to this species (as there are no other laomediids known from southern California) (Don Cadien, personal communication).

In January of 2004, a specimen of *Naushonia macginitiei* was collected from a large, shallow eelgrass (*Zostera marina*) bed south of Silver Strand Beach in San Diego Bay, California, marking the first time the species has been collected in nearly 70 years (apart from the unpublished observations noted above). The specimen, apparently only the sixth of this species ever recorded in print, was photographed soon after collecting, allowing us to comment on the coloration of the species for the first time.

Methods and Materials

Collection of the specimen was made by Brendan Reed and Lindsay Sirota as part of an ongoing San Diego State University master's thesis project focusing on the effects of harvesting eelgrass beds. The study site is San Diego Bay, a crescent shaped bay extending 25 km south from its mouth located near Point Loma (Fig. 1).

Study plots are in a large continuous eelgrass meadow (*Zostera marina*) located in southern San Diego Bay, just south of Silver Strands State Beach (Fig. 1). This expansive bed is fairly uniform in topography and is never fully exposed, although at extreme low tides the grass can be less than 1.5m deep. The currents in the south bay are quite mild, and water residence time can exceed a month. The sediment at this site consists of fine mud particles.

The specimen was collected during faunal surveying in January 2004. Epifauna were sampled with a 0.25m^2 throw-trap consisting of a circular metal frame with an attached 2mm vexar mesh collar that stands 1m high. The narrow opening of the conical collar (30 cm diameter) keeps epifauna from escaping the throw trap in field trials. Each throw trap was sampled with a diver-operated airlift suction sampler for one minute. Epifauna were collected into a narrow mesh bag (1600μm), rinsed and transferred into a plastic storage bag where they were frozen for future sorting in the laboratory.

The specimen was collected from a plot that had approximately 20% eelgrass removed by way of the scarring method, which removes large portions of eelgrass including all aboveground shoots and attached rhizomes. Sampling was conducted from late morning to early afternoon and in water no deeper than 2.5m. Photographs, taken with a digital Nikon Coolpix 995 (3.3 megapixel), were made shortly after the specimen was defrosted and sorted.

The specimen is deposited in the Crustacea collections of the Natural History Museum of Los Angeles County as LACM CR 2004-002.1.

Morphology

The specimen is immediately identifiable as a species of *Naushonia* by the elongate, subchelate, and somewhat oversized chelipeds (approximately equal in length to the carapace in this species and in most others; Fig. 2A, B), the sculptured carapace with well-developed linea thalassinica and broad, short rostrum (Fig. 2A, C), the similar morphology of pereiopods 3–5 but the distinctly different dactylus of pereiopod 2, the well developed suture on both uropods, and other characters of the genus (see Goy and Provenzano 1979; Alvarez *et al.* 2000). Our specimen in general agrees well with the original description given by Glassell (1938). Goy and Provenzano (1979), comparing USNM specimens of *N. macginitiei* (including the ovigerous female paratype) with those of other species in the genus, noted slight intra-specific variability in the number of teeth on the margin of the antennal scale (7 or 8), number of movable spines on the dactylus of the third pereiopod (20–22 in the paratype; up to 24 in two other specimens) and fourth pereiopod (15 to 18 spines). Carapace length of the specimens measured by them ranged from 7.6 mm in the paratype (the largest known to them) to 6.5 mm in USNM 144492 (which is actually USNM 171606 according to K. Reed; see below). Measurements and meristic counts in our specimen fall within these ranges, and the carapace length of our specimen (7.7 mm) is only slightly larger than the largest known specimen to date (the female paratype, measured by Goy and Provenzano [1979] at 7.6 mm carapace length). The abdomen length of our specimen is approximately 11.5 mm (approximate because of the bend of the abdomen), for a total length (rostrum to tip of telson) of approximately 19.2 mm.

The color in life is a surprisingly bright orange, with some of the appendages speckled with white or beige, lending an almost banded appearance to the pereiopods, and with the dorsal surface of the abdomen a more uniform beige or cream (Fig. 2). To our knowledge, this is the first observation of coloration in this species.

Known Distribution and Habitat

To date, *Naushonia macginitiei* has been reported only twice in the literature, first by Glassell (1938) in the original description (as *Homariscus macginitiei*)

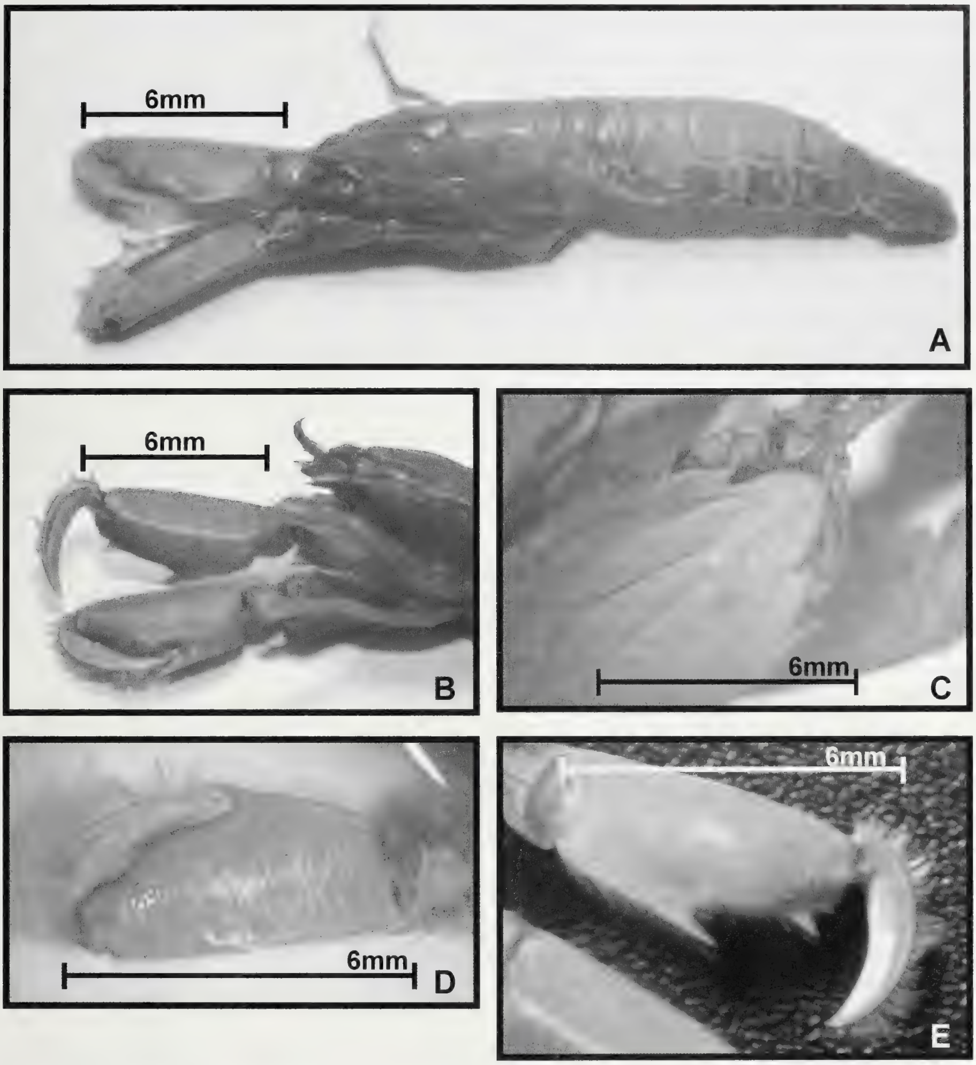

Fig. 2. LACM CR 2004-002.1, specimen of *Naushonia macginitei* (Glassell) from San Diego Bay described herein. A, entire specimen, dorso-lateral view. B, right and left chelipeds. C, rostrum and front half of carapace, dorsal view. D, right chela. E, opened left chela.

and later by Goy and Provenzano (1979). Goy and Provenzano (1979) examined additional specimens housed at the USNM, but did not give details of where those specimens were collected. The additional material discussed by Goy and Provenzano included collections made the Allan Hancock Pacific Expeditions using the R/V *Velero III,* and these records extended the known range south to Sonora, Mexico, and to Costa Rica (see below). In our introduction, we mentioned unpublished records of an additional 6 specimens, all collected from San Diego Bay and, interestingly, from depths of 4 to 11 m rather than the intertidal.

Glassell (1938) indicated that the holotype, one of two ovigerous females from La Jolla, California, was deposited in San Diego and assigned "cat. no.1120, San Diego Society of Natural History." The holotype now resides in the San Diego

Natural History Museum where it is catalogued with the following information: *Homoriscus macginitiei*; holotype #3924; Crustacea acc.no. 1120; 1 specimen; female (with 1120 on the tag in the jar); "Glassell 1938, p 414" written on the label (pers. comm., Paisley Cato, San Diego Natural History Museum). The other female (the paratype) was deposited at the USNM, where it is now catalogued as USNM 171605 (see below)

Apart from the holotype, the known collections of this species (all housed at the USNM) are as follows (K. Reed, USNM, pers. comm):

USNM 155480, *Naushonia* cf. *macginitiei* (Glassell), North Pacific Ocean, Wafer Bay, Cocos Island: 5° 32′ 45″ North 87° 00′ 10″ West, rocky shoreline, coll. 1 March 1933, Allan Hancock Pacific Expedition, Velero III, station 105-33, identified by T. Biffar.

USNM 171604, *Naushonia macginitiei* (Glassell), Pacific Ocean, Newport Bay, California, 33° 36′ 58″ North 117° 54′ 12″ West, North and East of highway 101 bridge, intertidal, −1.6 ft. tide, dredged sand flats along shore, coll. 18 December, 1941, Allan Hancock Pacific Expedition, Velero III, station 1442-41, identified by O. Hartman.

USNM 171606, *Naushonia macginitiei* (Glassell), North Pacific Ocean, Gulf of California, Ensenada De San Francisco, Sonora, Mexico, coll. 30 March 1937, Allan Hancock Pacific Expedition, Velero III, station 739-37, identified by J. W. Goy.

USNM 171605, *Homoriscus macginitiei* Glassell (Paratype), 1 female, North Pacific Ocean, La Jolla, California, U.S.A., coll. 4 March 1935 (by G. MacGinitie), identified (described) by S. A. Glassell.

Goy and Provenzano (1979) must have been unaware of the Costa Rica record sent to us by K. Reed (USNM 155480 above), as it is not among the USNM material they listed. According to Karen Reed (USNM), there are also two minor errors in the paper by Goy and Provenzano: the lot they listed as USNM 144492 is actually USNM 171606, and there is only 1 specimen (rather than 2) in that lot (K. Reed, pers. comm.). However, Goy and Provenzano provided measurements and detailed anatomical observations for the two specimens in that lot, so there is some uncertainty surrounding the specimen(s).

To these records we now add the new specimen from San Diego Bay (LACM CR 2004-002.1), very close to the type locality. Thus, the known range of the species is from southern California south to Sonora, Mexico, and to the Gulf of Nicoya, Costa Rica.

Although all members of the genus *Naushonia* are assumed to be burrowers in mud or sand (e.g. see Goy and Provenzano 1979; Alvarez *et al.* 2000), there has always been some question as to the habitat of *N. macginitiei.* Glassell (1938) noted that the original 2 specimens were found (by G. E. MacGinitie) "in a small pool at extreme low water, after he had turned some stones in search of *Typhlogobius californiensis* Steindacher (the Blind Goby)". In addition to these two southern California specimens, two additional individuals were also collected from intertidal habitats, one from the Cocos Islands and the other from Newport Bay. Our finding of *N. macginitiei* in a large and rather uniform eelgrass meadow might indicate that the species can occur in more than one type of habitat. As this is the only known specimen collected in eelgrass it is difficult to speculate as to the importance of this habitat to *N. macginitiei.*

Acknowledgments

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NOTE ADDED IN PROOF

While the current paper was in press, the following publication, which expands the known range of the genus *Naushonia* to the western Pacific, came to our attention:

Komai, T. 2004. Rare mud shrimp genus *Naushonia* Kinglsey (Decapoda: Thalassinidea: Laomediidae) from Japan: description of a new species and new record of *N. lactoalbida* Berggren. Crustacean Research 33: 15–26.

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Berggren, M. 1992. *Naushonia lactoalbida,* new species (Decapoda: Thalassinidea: Laomediidae), a mud shrimp from Inhace Island, Moçambique. J. Crustacean Biology, 12: 514–522.

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Goy, J.W. and A.J. Provenzano Jr. 1979. Juvenile morphology of the rare burrowing shrimp *Naushonia crangonoides* Kingsley, with a review of the genus *Naushonia* (Decapoda: Thalassinidea: Laomediidae). Proc. Biol. Soc. Wash. 92:339–359.

Martin, J.W. and L.G. Abele. 1982. *Naushonia panamensis,* new species (Decapoda: Thalassinidea: Laomediidae) from the Pacific coast of Panama, with notes on the genus. Proc. Biol. Soc. Wash. 95(3):478–483.

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The Scythe Butterflyfish, *Prognathodes falcifer* (Pisces: Chaetodontidae), Observed as a Facultative Cleaner

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Cleaning behavior in fishes is a well-documented phenomenon and involves a number of teleostean families (Limbaugh 1961; Deloach 1999). This behavior is expressed especially well in tropical gobies (Gobiidae), wrasses (Labridae), and butterflyfishes (Chaetodontidae).

While surveying fish and invertebrate populations using SCUBA at Islas San Benito, Baja California, Mexico (ca. lat. 28°18.7′N, long. 115°32.6′W) we observed cleaning behavior by the scythe butterflyfish, *Prognathodes falcifer* (Hubbs & Rechnitzer, 1958). This, to our knowledge, is the first report of cleaning behavior by this species; the nature of its cleaning also appears to be unique within the Chaetodontidae.

On 9 August 2001 at ca. 0820, at San Benito del Este, the easternmost of the three San Benito islands, we observed a large kelp bass, *Paralabrax clathratus,* and several scythe butterflyfish, at a depth of ca. 17 m in a relatively small horizontal cave. The dimensions of the cave (or large horizontal crevice) were ca. 2 m in length, 1 m deep, and 0.75 m in height.

The kelp bass was inside the cave and oriented horizontally and essentially parallel to the cave opening. Initially, we were impressed by its unusually large size, ca 600 mm total length. Several scythe butterflyfish were also noticed in the cave but at each end and not in close association with the kelp bass. The kelp bass then appeared to become rigid in posture and lower (or drop) its pectoral fins. Almost immediately, three butterflyfish (all ca. 150 mm total length) swam to the sides of the kelp bass, took diagonal positions, and appeared to start cleaning the larger serranid; we assumed they were picking external parasites (Fig. 1). One butterflyfish took a position to the anterioventral portion of the host kelp bass while the other two butterflyfish took posteriorventral positions on the body, one fish on each side. We observed this behavior for ca. 30 seconds.

The prolonged snout and jaw structure of the scythe butterflyfish appears to be preadapted for cleaning (Ferry-Graham et al. 2001). The barberfish, *Johnrandallia nigrirostris,* another eastern Pacific chaetodontid, is a well-documented cleaner (Hobson 1965, 1969; Burgess 1978; Allen 1979; Thomson et al. 2000).

The majority of butterflyfishes exhibiting cleaning behavior appear to clean their host while it is positioned up in the water column, perhaps making themselves more visible to the cleaners (Burgess 1978). In the example we observed, the host took a position in a somewhat secluded situation that harbored several

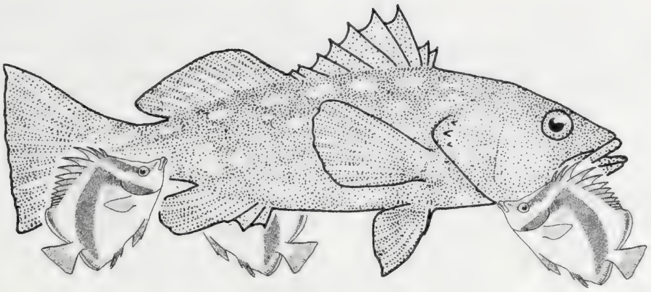

Fig. 1. Depiction of scythe butterflyfish cleaning a kelp bass at Islas San Benito on 9 August 2001.

scythe butterflyfish, one of the more secretive species of chaetodontids. In the case of *Prognathodes falcifer,* it is likely that cleaning is a non-obligate and infrequent mode of behavior. In over one hundred dives by us at the San Benito islands, covering an 18-year period, this is the first instance of cleaning by the scythe butterflyfish that we have witnessed. John McCosker of the California Academy of Sciences (pers. comm., April 2002), in many years of diving at the Galapagos Islands has never noted this species to be involved in cleaning. Perhaps secretive or clandestine cleaning is a more common mode of behavior than realized in chaetodontids. Additional observations of cleaning behavior by other cave- and crevice-dwelling species may be noted as a result in the future.

Acknowledgments

We thank John McCosker for providing comments and sharing his observations of scythe butterflyfish at the Galapagos Islands. Daniel Pondella was a dive partner during the 2001 San Benito trip and provided valuable comments. Larry Allen, Mark Helvey, Timothy Tricas and three anonymous reviewers also provided comments to the manuscript. Briana Brady prepared the illustration.

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Record of a White Sturgeon, *Acipenser transmontanus* from Bahía De Todos Santos, Baja California, Mexico, Found at the Ensenada Sea Food Market

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The white sturgeon, *Acipenser transmontanus* (Richardson 1836), is an anadromous fish that lives primarily in freshwater or estuaries, and infrequently meanders in the ocean. Most of fish are found in river systems, with the Sacramento-San Joaquin River system (California) and Columbia River system (Oregon/Washington) containing the largest populations (Love 1996). In summer, they migrate into shallow warm waters of rivers or toward the shores for breeding purposes. They are benthic and long-lived fish species that inhabit the shallow sand and mud bottoms (Love 1996). The distribution of *Acipenser transmontanus* range from Northern Baja California (Love 1996), or from Ensenada, Baja California (México) to Gulf of Alaska (Miller and Lea 1972).

Bahía de Todos Santos is located at Ensenada, Baja California, México, (31°40′–31°56′N, 116°36′–116°50′W), and fish studies at the bay began in the early 1980's with a variety of gear types including spear guns at kelp beds (Díaz-Díaz 1983; Díaz-Díaz and Hammann 1987), trawl tows on sandy bottoms Hammann and Rosales-Casián (1990), and creel surveys (Rodriguez-Medrano 1993). In addition, research on the fish community of Todos Santos bay and also in Bahía and Costa de San Quintín was conducted between 1992 and 1995 using five different gears: beam-trawl, otter-trawl, beach-seine, gillnet, and hook-and-line (Rosales-Casián 1997a, 2004). Recently, a study of the artisanal fishery from eight fishing camps along northwestern coast of Baja California was also completed (Rosales-Casián and Gonzalez 2003). All those studies failed to collect any specimens of white sturgeon.

The Seafood Market of Ensenada Port has been surveyed monthly since September 2000 (Hernandez-Hernandez 2002). During this monitoring program on March 15, 2003, we observed a white sturgeon (*Acipenser transmontanus*), which was captured on same day with a bottom trap close to the Isla de Todos Santos located in Bahía de Todos Santos. The specimen was fresh and complete but eviscerated, and the testes were still in the body. This male was in stage III: maturation (Nikolsky 1963; Cailliet *et al* 1986). The white sturgeon was 1,228-mm total length (TL) and a somatic weight of 6,366 g. In California waters, the males mature at TL 1,097–1,828 mm (Love 1996).

The white sturgeon was identified by the combination of the following characteristics: body coloration was grayish-white with five rows of bony plates (scutes) on its body. The head was short and robust with the four long barbells (5cm) located in the front and closer to the snout tip than to the mouth. The mouth was underneath the head, and the number of the midlateral bony plates was 40.

Another white sturgeon, *Acipenser transmontanus,* was collected at Flat Rock, Rancho Palos Verdes in Los Angeles County on April 24, 2003. SL 1,220, TL 1,940, and 20.5 kilos. It was caught in an overnight gill net set as part of a white seabass monitoring project (Pondella and Allen 2000). Latitude 33°47′54′′N, Longitude 118°24′73′′W, depth 6.3 meters (Daniel Pondella, personal communication, Vantuna Research Group, Occidental College, Los Angeles, CA).

The record of this specimen is important because it reconfirms the southern range of white sturgeon, increases the list of fish species that have been collected or registered at Bahía de Todos Santos, Baja California, México, and re-establishes a well-documented reference.

Acknowledgments

We thank the fish vendors at the Mercado de Mariscos del Puerto de Ensenada, to allow our study and by the inconveniences of the fish handling during their operations.

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Brattstrom, B. H. 1969. The Condor in California. Pp. 369–382 *in* Vertebrates of California. (S. E. Payne, ed.), Univ. California Press, xii + 635 pp.

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Cover: Bottlenose dolphins socializing in Santa Monica Bay, CA. Photo: Maddalena Bearzi